Volume 6 April, 1927 Number 4

JOURNAL

OF THE

AMERICAN WELDING SOCIETY

Published Monthly by the American Welding Society
33 West Thirty-ninth Street, New York

American Welding Society

OFFICERS FOR 1926-27

F. M. FARMER, *President*
E. M. T. RYDER, *Senior Vice-President*
C. A. MCCUNE, *Treasurer*
M. M. KELLY, *Secretary*
R. L. BROWNE, *Vice-President*
A. M. CANDY, *Vice-President*
STUART PLUMLEY, *Vice-President*
GEORGE BIRD, *Vice-President*
G. O. WILSON, *Vice-President*

DIRECTORS

(Officers listed above are also members of the Board of Directors)

Term Expires 1927	*Term Expires* 1928	*Term Expires* 1929	*Section Representatives*
J. H. DEPPELER	JAMES BURKE	C. A. ADAMS	C. W. BATES
E. M. T. RYDER	J. W. MEADOWCROFT	A. G. BISSELL	J. C. BENNETT
W. A. SLACK	H. A. WOOFTER	A. E. GAYNOR	H. P. DOUD
T. F. BARTON	S. W. MILLER	H. M. HOBART	H. D. KELLEY
	E. H. EWERTZ	A. G. OEHLER	J. C. LINCOLN
			J. W. MORRISSEY
			W. L. WARNER
			W. A. SLACK
			G. W. SWAN
			F. E. ROGERS

PAST-PRESIDENTS

C. A. ADAMS (1919-20)
J. H. DEPPELER (1920-21)
S. W. MILLER (1921-22)
C. A. MCCUNE (1922-23)
T. F. BARTON (1923-24)
E. H. EWERTZ (1924-25)
A. G. OEHLER (1925-26)

CHAIRMEN, STANDING COMMITTEES

Executive—F. M. FARMER
Finance—C. A. MCCUNE
By-Laws—A. M. CANDY
Meetings and Papers—P. W. SWAIN
Membership—J. J. FLAHERTY

W. SPRAGAGEN, *Editor, Journal*

American Bureau of Welding

(RESEARCH DEPARTMENT OF SOCIETY)

OFFICERS

C. A. ADAMS, *Director*
H. L. WHITTEMORE, *1st Vice-Director*
A. D. RISTEEN, *2nd Vice-Director*
WM. SPRAGAGEN, *Secretary*

CHAIRMEN, RESEARCH COMMITTEES

Electric Arc Welding—H. M. HOBART
Gas Welding—S. W. MILLER
Welded Rail Joints—G. K. BURGESS
Structural Steel—J. H. EDWARDS
Welding Wire Specifications—C. A. MCCUNE
Pressure Vessels—E. H. EWERTZ
Thermit Welding—J. H. DEPPELER

JOURNAL

OF THE

AMERICAN WELDING SOCIETY

Copyright 1927, by the American Welding Society,
33 West Thirty-ninth Street, New York

Subscription $10.00 per year to United States. $11.00 to Canada. Libraries $5.00.
Back numbers, per copy: Members, $0.50; Non members, $1.00.

The Society is not responsible for any statement made or opinion expressed in its publications. Permission is given to reprint any article after its date of publication, provided proper credit is given.

Volume 6 **APRIL, 1927** **Number 4**

TABLE OF CONTENTS

Society and Related Activities

Page

Program Annual Meeting 3
Lincoln Prizes for Welding 5
Testing Welding 7
Dependability 8
Section Activities 8
Employment Service Bulletin 10

Technical Papers, Items and Reports

Fatigue of Welds 11
Replacing Castings by Welded Steel Parts 33
Structural Steel Welding Investigations by Westinghouse Co. 41
Research Activities of the Metal and Thermit Corporation 43
Research Activities of Una Laboratory 46
Developments and Research in Welding 48
Welding Researches of the Newport News Shipbuilding & Dry Dock Co. 59
Resistance Line Welding 74
Arc Welding of Buildings 82
Current Welding Literature 88

SECTION OFFICERS AND HEADQUARTERS

PHILADELPHIA

Engineers' Club, 1317 Spruce St., Philadelphia, Pa.

Chairman—P. A. L. Maurhoff, District Manager, Oxweld Acetylene Co.
Secretary—H. E. Hopkins, 709 W. Huntington St., Philadelphia, Pa.

CHICAGO

802 *Marquette Building, Chicago*

Chairman—Jonathan Wolfe, Chicago Surface Lines.
Secretary—Stuart Plumley, Editor, Acetylene Journal.

PITTSBURGH

1841 *Oliver Bldg., Pittsburgh*

Chairman—J. D. Conway, Secretary-Treasurer, Railway Supply Mfg. Assn.
Secretary—H. E. Hollis, P. O. Box 681, Pittsburgh, Pa.

NEW YORK

33 *West Thirty-ninth Street, New York*

Chairman—F. E. Rogers, Air Reduction Sales Co.
Secretary—A. F. Keogh, Sound Welding Company.

NORTHERN NEW YORK

General Electric Co., Schenectady

Chairman—R. E. Wagner, General Electric Co.
Secretary—F. M. Jefts, General Electric Co.

CLEVELAND

2200 *Chester Avenue, Cleveland, Ohio*

Chairman—Herbert M. Boylston, Case School of Applied Science
Secretary—R. K. Randall, Cleveland Y.M.C.A., 2332 Prospect Ave., Cleveland.

SAN FRANCISCO

Rialto Building, San Francisco

Chairman—W. P. Brown, Brown Bros. Welding Co.
Secretary—W. B. Sawyer, Jr., United States Steel Products Company.

LOS ANGELES

420 *So. San Pedro Street*

Chairman—S. Barton Brown, Barton Brown Engineering Corp.
Secretary—J. Max Lee, Westinghouse Elec. & Mfg. Co.

BOSTON

Engineers' Club, 2 Commonwealth Avenue, Boston, Mass.

Chairman—J. A. Shand, Air Reduction Sales Co., Dorchester, Mass.
Secretary—H. P. Peabody, J. A. Roebling's Sons Co.

WESTERN NEW YORK

509 *Morgan Bldg., Buffalo, N. Y.*

Chairman—Robert Siemer, Allan Mfg. & Welding Co.
Secretary—C. D. Miller, Burke Electric Co., Buffalo, N. Y.

DETROIT

Chairman—W. C. Sprau, Barnes Wire Fence Co.
Secretary—A. W. Fry, C. A. Strelinger Co., 149 Larned St. E., Detroit, Mich.

PORTLAND

524 *Oregon Building*

Chairman—J. S. Beall, Beall Pipe & Tank Corp.
Secretary—Samuel Powell, United Metal Trades Association.

AMERICAN WELDING SOCIETY

ESTABLISHED 1919

JOURNAL

Volume 6 APRIL, 1927 Number 4

PROGRAM

ANNUAL MEETING

of the

AMERICAN WELDING SOCIETY

33 West 39th Street, New York, N. Y.

April 27, 28 and 29, 1927

All Sessions Start Promptly as Scheduled

IMPORTANT NOTICE

Members and their guests are requested to register.

WEDNESDAY, APRIL 27, 1927

Committee Meetings

All Members of Society are Welcome!

Morning

Gas Welding Committee, S. W. Miller, Chairman

9:30 a. m. to 12, Room 1101.

A review of progress; suggestions for desirable researches and method of carrying them out.

Electric Arc Welding Committee, H. M. Hobart, Chairman
9:30 a. m. to 12, 10th Floor.

Analysis and discussion of the tests results made by the welding committee of the Emergency Fleet Corporation to determine certain fundamentals in connection with Electric Arc Welding.

Afternoon

Annual Meeting, American Bureau of Welding, C. A. Adams, Director, 2:00 p. m. to 5 p. m., 10th Floor.

A review of progress made by various research committees of the American Bureau of Welding. Plans for future investigational activities. Election of Officers and Executive Committee.

THURSDAY, APRIL 28, 1927

Morning

Technical Session

9:30 a. m. to 12, Room 2, 5th Floor, E. H. Ewertz, Presiding Officer.

Report of Tellers' Committee

A symposium of research activities in the welding field during the past three years.

1. C. A. McCune, Page Steel and Wire Company.
2. J. H. Deppeler, Metal & Thermit Corporation.
3. R. R. Moore, Chief Physical Testing Branch, War Department, Air Service, McCook Field.
4. J. J. Crowe, Air Reduction Sales Company.
5. J. W. Owens, Director of Welding, Newport News Shipbuilding & Dry Dock Company.
6. R. B. Fehr, Una Welding and Bonding Company.
7. D. H. Deyoe, General Electric Co.
8. W. J. Beck, American Rolling Mill Company.
9. A. G. Bissell, Westinghouse Electric & Mfg. Company.
10. J. R. Dawson, Union Carbide & Carbon Research Labs.

Luncheon

A luncheon for members of the Society has been arranged at the Engineers' Club. Tickets at $2.00 each may be obtained from the Secretary.

Afternoon

Tehnical Session

2:00 p. m. to 5, Room 2, 5th Floor, E. M. T. Ryder, Presiding Officer.
Symposium on Production Welding.

In order to indicate the wide field of application of welding, six or seven specific applications to production work have been selected representing the several welding processes. A series of short papers will be given, each dealing exhaustively with one specific application, including cost figures, design data, technique of welding, jigs, method of testing, products, etc. These papers include:

1. **Production Welding of Stern Frames.** J. H. Deppeler, Metal and Thermit Corporation.
2. **Replacing Castings by Welded Structural Parts.** J. F. Lincoln, Lincoln Electric Company.
3. **Application of Arc Welding to Houses and Buildings.** C. J. Holslag, Electric Arc Cutting and Welding Company.
4. **Oxy-acetylene Welding of Furniture.** M. F. Bayer, Simmons Company.
5. **Resistance Welding Paper.** Title and author to be announced later.
6. **Applications of Welding in Automobile Manufacture.** Robert Appleton, Engineer, Pierce-Arrow Mfg. Co.

Evening

Dinner Dance

6:30 p. m. Hotel Commodore.

Following the precedent established last year, the Annual Dinner of the American Welding Society will be followed by a dance and, of course, all the ladies are especially invited to attend. The dinner-dance will be held at the Hotel Commodore. Plans include the banquet with a Presidential Address by President Farmer; the announcement of the election of new officers and some special entertainment features of interest to both ladies and members of the Society.

Dinner tickets should be secured in advance from the Secretary at $6.00 each.

FRIDAY, APRIL 29, 1927

Morning

Board of Directors

9:30 a. m. to 12, Room 1101.

Meeting of Board of Directors, American Welding Society

Appointment of Committee Chairmen and other Officers. Committee reports. Discussion of Section Activities. Plans for coming year.

Afternoon

Joint Pressure Vessel Committee

Members of the A. W. S. Interested in the Subject May Attend This Meeting

Meeting of Joint Pressure Vessel Committee of A. S. M. E. and A. B. W., E. H. Ewertz, Chairman

2:00 p. m. to 5, Room 1101.

Review of progress made by Subcommittees on Tests and Procedure. Plans of investigational work.

ENTERTAINMENT FOR LADIES

Special Entertainment is being provided for lady guests of the members who register.

Note: To partially defray the cost of this entertainment, members are required to pay a registration fee of $1.00 for each lady registered.

A Luncheon and Bus Ride are being arranged for WEDNESDAY, APRIL 27th, and a Matinee at Roxy's Theatre on THURSDAY, APRIL 28th.

Details as to place and time of each event may be obtained at Society Headquarters on the first day of the meeting, WEDNESDAY, APRIL 27th.

OFFICIAL STATEMENT OF CONDITIONS GOVERNING THE AWARD OF LINCOLN ARC WELDING PRIZES FOR 1927

By the American Society of Mechanical Engineers

The American Society of Mechanical Engineers has accepted the custody of seventeen thousand five hundred dollars ($17,500), offered by The Lincoln Electric Company of Cleveland, Ohio, to be awarded by the society in a world-wide competition for the best three papers disclosing advancement in the art of arc welding, presented under the rules of the competition. Three prizes will be awarded—$10,000, $5,000 and $2,500—provided the papers are of sufficient importance and value to justify, in the opinion of judges appointed by the Society, the awarding of such prizes.

The American Society of Mechanical Engineers, in accepting this trust at the request of The Lincoln Electric Company, which is moved by a sincere desire to improve the art of arc welding and to reduce the cost of carrying out designs and processes, does so with the sole motive of assisting in promoting industrial development. In administering this trust, the Society assumes no responsibility for the content of the papers. It will confine itself to the appointment of a Committee of Judges who will pass upon the relative merits of these papers and recommend the awards. The council, the governing board of the Society, will make the awards at a meeting of the Society.

Purposes of the Competition

The purpose of the prizes has been expressed by the donor as follows:

The commercial progress of the world has been dependent largely on the discovery of certain important methods or machines. Thus, the steam engine began our present industrial era; high-speed steel and alloy steel mark milestones in our progress, which have been instrumental in greatly reducing costs and hence increasing prosperity. Mass production is another step which undoubtedly increased output and hence lowered costs in an impressive way. There have been many other advances of equal or less importance which, collectively, have changed the economic status of mankind to the point where the most lowly laborer of today enjoys, as a matter of course, conveniences which the most famous and powerful monarch of one hundred years ago could not have.

It is believed that another important step in industrial development will be made by a more extensive use of arc welding.

The importance of this step is not fully realized by most people. It means much more than the simple joining of parts. The replacement of the riveted or bolted joint by welding will make possible a reduction in weight and cost of machines and structures. Arc welding may also permit an advantageous substitution of one metal for another.

As an illustration, it is possible in some cases, through the application of the arc welding process, to substitute steel members for castings, and thus to bring about advantages and substantial economies.

In view of these possibilities, the purpose of this competition is to encourage improvements in the art of arc welding, the pointing out of new and wider applications of the process, the discovery of improved methods of testing welds to assure their integrity, or indicating advantages and economies to be gained by its use.

The Lincoln Arc Welding Prizes will be awarded to the authors of the most valuable papers suggesting means and methods for carrying out any or all of the above purposes. The prizes are as follows:

For the best suggestion, $10,000.

For the next best suggestion, $5,000.

For the third best suggestion, $2,500.

Rules of the Competition

The competition will be judged by a committee of The American Society of Mechanical Engineers, in accordance with the following rules:

1. Anyone, in any country of the world, may compete for these prizes.

2. All papers must be written in duplicate, in the English language, and submitted to the Council of The American Society of Mechanical Engineers, addressed to the Secretary, Calvin W. Rice, 29 West Thirty-ninth Street, New York, N. Y. All exhibits shall also be in duplicate, and captions, titles, legends and notes shall also be in the English language. All papers must bear evidence of having been sent before January 1, 1928, in order to be considered in this competition. Any paper arriving after January 31, 1928, will be disqualified.

3. Every paper should include all necessary drawings, photographs, or other exhibits, in order that the disclosure may completely present the suggestions of the competitor.

(*a*) The utility of the suggestions must be shown not only for the application but also for possible use in connection with other designs and for their purposes.

(*b*) The possible advantages and economies of the methods should be made clear, as these will be the chief bases upon which the winning papers will be selected.

4. The practicability of the suggestions must be evident from the paper. It is not necessary, however, that its actual application be fully shown, if possible uses are made clear.

5. Originality of design is preferable, either in the method of applying the weld or in the design of the welding parts for their arrangement. Designs which are of no practical use will only be considered in case they include suggestions which could self-evidently be applied in other ways than those suggested. Methods of applying the arc or the welding art which will improve existing machines, or make commercially possible machines which, in the light of previous engineering, have been regarded as impractical, are specially desired.

6. It is not necessary that all parts of the structure should be made of welded metal. It is only necessary that one or more parts be so made.

7. In case two or more identical suggestions are received, the one bearing the lowest serial number assigned to the paper on its receipt by the Secretary of The American Society of Mechanical Engineers will have precedence. Because of this rule, competitors are urged to submit their papers as soon as they are prepared.

8. The Council of The American Society of Mechanical Engineers may withhold any or all awards.

9. Each paper must be typewritten on one side of 8½ in. x 11 in. paper and bound at the top with a protecting cover or jacket. The name and address of the competitor must appear on the front cover. Both copies of each paper must be enclosed within a sealed envelope, on the outside of which will be placed the name and address of the competitor and the following legend: "Submitted to The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y., in competition for the Lincoln Arc Welding Prize." This sealed envelope must be enclosed within a mailing wrapper. The receipt of each paper will be acknowledged.

10. The Committee of Judges will not pass upon the acceptability of any apparatus suggested as a proper subject for this competition.

11. In submitting papers, each competitor gives to The American Society of Mechanical Engineers the right to publish his paper, should the Society desire to do so in any of its several publications. No papers will be returned to any competitor.

12. The decision of the Committee of Judges in interpreting the foregoing Rules will be final.

Suggestions

For aid in preparing papers it is recommended that the small amount of literature available be studied to get the fundamental principles which govern re-design. Numerous articles have appeared in the technical press which will be valuable, and certain companies have done much work that will be helpful in getting out a paper.

Time of the Award

It is the purpose of The American Society of Mechanical Engineers to present these awards at the stated 1928 Spring Meeting of the Society. All competitors will be properly notified of the action of the Judges.

The above is taken from a pamphlet issued by the A.S.M.E. This pamphlet also contains suggestions to entrants by the Lincoln Electric Co.

RIVETERS AND WELDERS SMOKE PEACE PIPE

Reprinted from Daily Metal Trade of February 24, 1927.

It is gratifying to note, as published elsewhere in this issue, that the question of joining steel to steel no longer is as controversial as it was only a short time ago. At the meeting at the Engineers' Club, Philadelphia, Monday night, proponents of riveting and of welding naturally talked about the merits of their respective methods. But there was a disposition to make statements in moderation, to understand each other and to cooperate.

Progress in Harmony

An expression at the meeting which obtained hearty indorsement

was to the effect that welding will not displace riveting; that the two methods would march on together, side by side. This is a good view to take. Riveting has a long, successful history and today, because of recent developments in machinery, is being done more efficiently than ever. Welding is new and presents many problems for solution; nevertheless, the method is being used widely and successfully. Welding undoubtedly has a big future. But indications to date certainly are not calculated to alarm those interests who are identified with riveting.

TESTING WELDING

Reprinted from Power, March 22, 1927.

For the joining of metals, soldering and brazing have limitations which are soon reached. Good welds have long been made by hammering or forging, but except where special facilities have been available, this process has been confined to such work as could be handled in a forge.

For the joining of the members of structures, the plates of ships and of boilers, the frames of machinery, etc., the engineer has resorted to the use of rivets.

A riveted joint is not an embellishment to a structure. It adds weight, involves objectionable irregularities in thickness and surface protuberances, and a joint held tight only by the pressure of the sheets upon one another cannot be depended upon to remain entirely free from leakage.

But properly made, it is safe, and its proper making can be assured.

Developments in chemistry and electricity have made possible the local concentration of heat in large amounts and at high temperatures.

This has led to the possibility of joining metals by fusing the juncture and forcing them together, or by fusing a joining metal between them, so completely that the weld is often as strong as or stronger than the material joined.

But how can it be known that the weld is complete, that the joint is strong and ductile and that the metal in its vicinity has not been affected?

The tremendous effect of the general application of welding upon the design and construction of metal structures is obvious.

The thing that would most immediately conduce to such general adoption is the discovery of some simple, easily applicable method of demonstrating the integrity of the weld itself and the absence of impairment of the contiguous material.

Surely within the resources of the physicist who can dissociate the atom, there is something that will render perceptible the relations of the molecules within and about a weld.

F. R. Low.

DEPENDABILITY

(A communication to the Editor)

As time goes on and new inventions are made, new processes discovered and improved methods developed, there is much to be done along educational lines for the purpose of inspiring confidence in these things. This is not always an easy task, and certainly not one to be regarded lightly in any case. Human nature is a complex quantity which is subject to variations of the widest sort. These variations must be encountered and must be dealt with in an intelligent and effective manner for the benefit of all concerned.

The welding process is in the growing stages, and there is something new to be learned each day, for none of us knows all there is to know about welding. The welding process is afflicted with a certain weakness which the critics call the "personal variable," and according to those who judge the merits of industrial processes this weakness determines success or failure, depending upon the strength of that weakness. The secret of success is thorough training and intelligent selection, together with experienced supervision. This cannot be overemphasized.

We are sometimes led to believe that the "personal variable" is the whole thing in welding, and it is frequently forgotten that this condition also exists in other industrial processes.

It is sometimes difficult to understand objections which are made to the use of welding. These can be excused, perhaps, where they arise because of either an ignorance of what welding is or a fear that the users do not correctly understand its use. Education is needed in those instances, but it must be education, not propaganda. The ability to show successfully those who would like or those who require such proof is the best guarantee of the dependability of the welding process. There are many users of welding today who can do that very thing. Designing engi-

neers, fabricators and manufacturers are turning to welding for assistance in simplifying design, cutting fabrication costs and speeding up production.

To do these things requires a sincere desire to learn, an earnest attempt to apply the fundamental principles, and an intelligent supervision. The boss must be interested and willing to try. He must be open-minded and able to learn, for the weakness of the welding process, of course, is the "personal variable," and that applies not only to the welding operator, but also to the executive himself.

WILLIAM L. FRANKLIN.

March 15, 1927.

SECTION ACTIVITIES

Chicago

The election of officers of the Chicago Section took place on Friday evening, April 1, at their regular monthly meeting. The following officers were elected to serve for the coming year: Chairman, Ernest Lunn, Pullman Co.; vice-chairman, R. G. Longwell, Link-Belt Co.; secretary and treasurer, Stuart Plumley, Gas Products Association. Directors for three years, J. G. Norris, Central Steel & Wire Co.; J. M. Cameron, Imperial Brass Co.; Jonathan Wolfe, Chicago Surface Lines; H. E. Gennett, Chicago, Burlington & Quincy Railroad. Directors for two years, J. W. Haywood, Linde Air Products Co.; directors for one year, G. T. Horton, Chicago Bridge & Iron Works; Julius Kinsock, Standard Oil Co.; director to represent Chicago Section at the directors' meeting W. A. Slack, Torchweld Equipment Co.

The speaker of the evening was W. P. Madden, Industrial Department, General Electric Co., who delivered an address on "Estimating Costs on Welding," which was illustrated with lantern slides. Mr. Madden's paper was discussed by many of those present.

At the next meeting S. W. Miller, consulting engineer, Union Carbide and Carbon Research Laboratories, will present a paper on "The Design, Construction and Testing of Tanks," which will be illustrated by lantern slides.

Northern New York

At a meeting recently held in Schenectady, the following officers were elected to serve for the coming year: Chairman, C. L. Ipsen, G. E. Company; first vice-chairman, J. D. Wright, G. E. Company; second vice-chairman, G. R. Brophy, G. E. Company; secretary, F. S. Peasley, G. E. Company; treasurer, R. A. Weinman, G. E. Company. Two directors for three years, LeR. Beers, G. E. Company; V. J. Chapman, G. E. Company. One director for two years, W. P. Madden, G. E. Company. Director at large, D. H. Deyoe, G. E. Company.

The next meeting of the Northern New York Section will be held in Albany on April 25. It is planned to secure a speaker on Railroad Welding, whose address will be of wide interest.

Philadelphia

The April meeting of the Philadelphia Section will be held on the 18th. S. W. Miller, consulting engineer, Union Carbide and Carbon Research Laboratories, will present a paper on "Fusion Welding of Large Vessels." This paper will be illustrated by lantern slides. The annual election of officers will take place at this meeting.

Cleveland

The April meeting of the Cleveland Section was held on the 12th as a joint meeting with the American Society for Steel Treating and the Cleveland Engineering Society. Clayton M. Hoff, of the research department of the Grasselli Chemical Co., presented a paper on "Corrosion and Its Prevention."

During 1927-28 season it has been decided to hold meetings of the Section every other month. This will enable the Section to advertise its meetings more extensively and arrange for a greater attendance and more discussion.

Western New York

A meeting of the Western New York Section was held on April 12. R. L. Browne, of the Metal & Thermit Corporation, presented a review of "Metal Thermit Welding." Mr. Browne's paper was illustrated with lantern slides and was supplemented with motion pictures and actual demonstrations of thermit welding. At this meeting, J. H. Mallon, educational manager, Louisville Cement Company, presented a talk on "Masons' Cements." Exhibits were shown.

Pittsburgh

The Pittsburgh Section will hold its April meeting on the 15th. A. M.

Candy, general engineer, Westinghouse Electric & Mfg. Company, will present a review of "The Rational Design of Steel Structures for Arc Welding."

The author will describe briefly a series of test specimens, a few of the principal ones being considered. Also a few tests involving the subjection of steel structures to shock loading and vibration stresses, in addition to showing details of the construction of the Westinghouse company's Sharon building. Some other interesting data will be introduced relative to the tests at the Bureau of Standards last summer on the large girder for the American Bridge Company, this girder being constructed entirely of plate material arc welded to produce the girder. Paper will be illustrated by lantern slides.

Boston

The March meeting of the Boston Section was held on the 15th. Several hundred people were present. Dr. A. Krebs, General Welding & Equipment Company, demonstrated a welding torch with a three-flame system produced by two high intensity oxy-acetylene flames. Welding with this torch was shown on corner seams and with steel of different thicknesses. The welding of corner seams is a frequent occurrence on heater sections, boxes, etc. The demonstration with the new torch showed exceptional speeds, remarkable penetration and excellent ductility. Several operators were invited to try their hand and all found that the torch is very easy to handle, exceptionally speedy and produces a weld as if made by a machine. No welding rod was used.

As a second demonstration, Dr. Krebs explained the use of city gas for cutting work. By boosting the gas to 15 and 30 lbs. pressure with a special torch which concentrates the flame, city gas can be used for cutting purposes as readily as other gases.

A demonstration followed which showed that the faces cut by the city gas was very soft and the upper edges sharp and clean.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be addressed to the number indicated in each case and mailed to Society headquarters.*

POSITIONS VACANT

V-36. *Wanted at Once.* Electric Welder thoroughly experienced with use of G. E. arc welding machine, particularly for welding structural steel. In replying outline your experience and state salary desired and whether married or not.

V-37. Desire to secure foreman for electric welding department at our ship yard.

SERVICES AVAILABLE

A-56. Experienced welder desires position. Have had eight years' experience as an Oxy-Acetylene Welder of steel, cast iron, and brazing. Have worked for the Hoist & Body Company, Columbia Machine Company, Link Belt Company, Baker Iron Works and Southern Pacific Company. With each of the three latter companies I have worked from two to three years.

A-57. Electric Welder desires position. Have worked for Westchester Lighting Co., J. L. Harris, Welding Engineer and Contractor, and Electrolux Sewerl Company. Can furnish references.

Fatigue of Welds*

By R. R. MOORE†

The increased use of welding in industry demands a more intimate knowledge of the properties and characteristics of this method of joining metals. Very little attention has been paid to the effect of repeated stresses on the life (fatigue) of welded joints. With the application of welding to the members of rotating and reciprocating machinery and to structures subjected to vibration, the fatigue of welds becomes an important consideration.

A particular example of a structure subjected to considerable vibration is the fuselage of an airplane. The tendency today in airplane construction is toward the steel tube fuselage with welded joints. This type of construction offers the advantages of greater flexibility in design, lightness, low cost, rapid construction and simplicity of repairs. In such work it is rarely necessary to weld metal thicknesses greater than 3/16-in. and usually not over 1/16 in. The tests described herein relate to this type of welding rather than the welding of heavy sections.

METHOD OF TESTS

Outline of Tests:—Tension and fatigue tests were made on various types of specimens as follows:

1. *Gas Welding (Oxy-Acetylene):*
   a. Norway Iron Filler Rod—1 inch diameter x 1/16 inch wall tubes. Butt welded at McCook Field.
   b. Low Carbon Steel Filler Rod—1 inch diameter x 1/16 inch wall tubes. Butt welded by Air Reduction Corporation.
   c. Vanadium Steel Filler Rod—1 inch diameter x 1/16 inch wall tubes. Butt welded by Air Reduction Corporation.
   d. Chromium Molybdenum Steel Filler Rod—1 inch diameter x 1/16 inch wall tubes. Butt welded at McCook Field.
   e. Norway Iron Filler Rod—½ inch diameter x 1/16 inch wall tubes. Butt welded at McCook Field.
   f. Same—"cleaned up" (excess weld removed) to match wall of tube.
   g. Norway Iron Filler Rod deposited into sample bars and specimens made from them to determine properties of the deposited metal.
2. *Arc Welding (Metal Arc):*
   a. Steel Kote Filler Rod—1 inch diameter x 1/16 inch wall tubes. Butt welded at McCook Field.
   b. Steel Kote Filler Rod—½ inch diameter x 1/16 inch wall tubes. Butt welded at McCook Field.
   c. Same—"cleaned up" (excess weld removed) to match wall of tube.
   d. Steel Kote Filler Rod deposited into a pad and specimens made from it to determine properties of the deposited metal.
3. *Atomic Hydrogen Welding Process:*
   a. Filler Rod made from strips of the tube to be welded—1 inch diameter butt welded tubes, made by the General Electric Company.
   b. Same—"cleaned up" (excess weld removed) to match wall of tube.
   c. Filler Rod deposited into sample bars and specimens made from it to determine properties of the deposited metal.
4. *Cast Steel:*
   Bars of cast steel 2″ x 2″ x 18″ from which specimens were taken for determination of properties to be compared with deposited metal.

*To be presented at annual meeting A. W. S., April, 1927.
†Chief, Physical Testing Br. Air Corp., McCook Field.

The details of the welding procedure are given in Table I. The sample bars of gas deposited Norway iron were approximately ¾-in. diameter by 3¾ in. long. The sample bar of arc deposited steel Kote was made up into a pad by the "beading" process. This pad of deposited metal was about 9 in. x 12 in. x ¾ in. thick, exclusive of base plate.

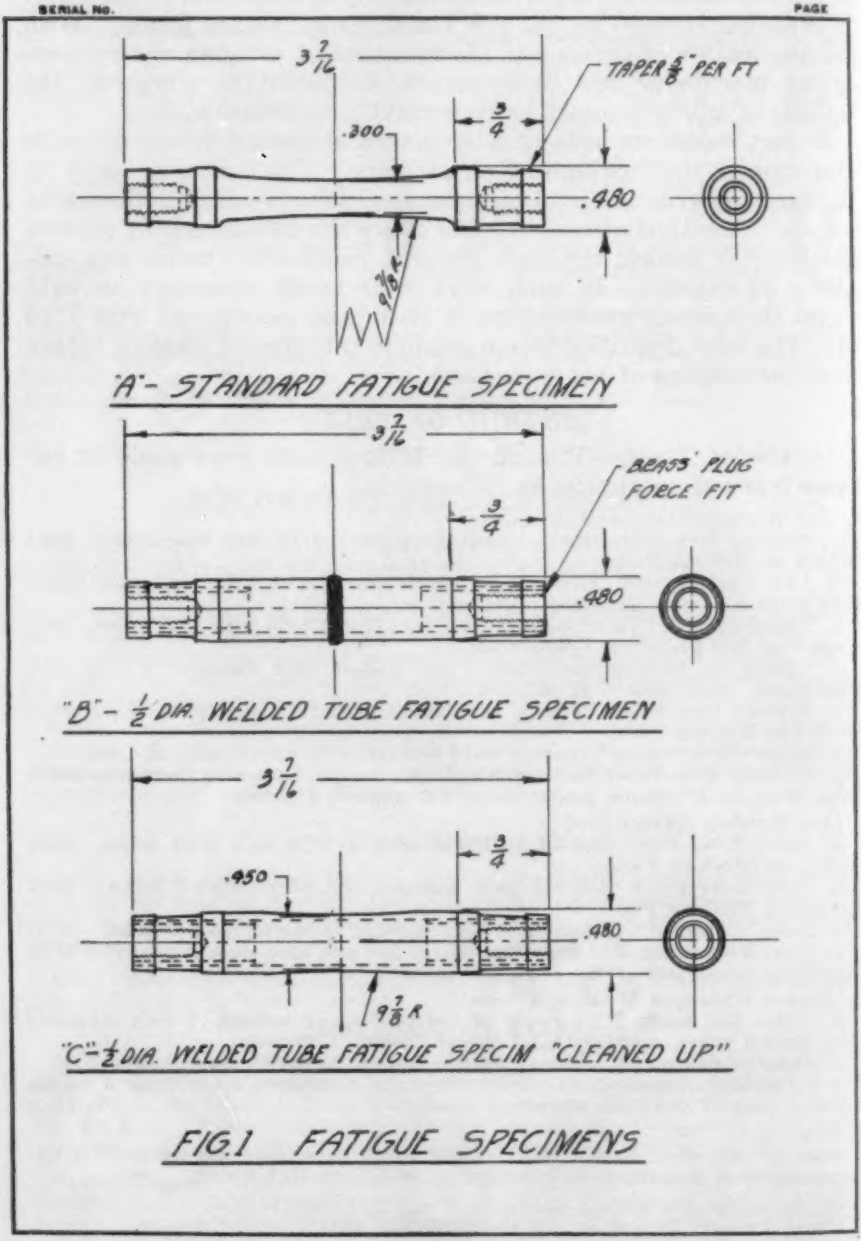


FIG. 1 FATIGUE SPECIMENS

TABLE I

Details of Methods of Welding

Type	Size of Filler Rod	Kind of Filler Rod Gas Weld	Analysis of Filler Rod C	Mn	P	S	Cu	Si	Va	Cr	Mo	Welding Apparatus
1		(*Oxy-Acetylene*)										
(a)	1/16	Norway Iron	.03	.12	.040	.045	.13					Welded by McCook Field.
(b)	1/16	Low Carbon Steel	.10	.18	.011	.024		.02				Welded by Air Reduction Co.
(c)	⅛	Vanadium Steel	.25	.43	.011	.025		.17	.15			Same
(d)	Strip .093	*Chrome Molybdenum*	.28	.61						1.14	.95	Same
(e)	1/16	Norway Iron	See 1(a)									McCook Field
(f)	1/16	Norway Iron	See 1(a)									Same
(g)	⅛	Norway Iron	.02	.14	.040	.027	.14					Same
												Acetylene pressure, 5 lb.; oxygen, 10 lb. pressure.
2		Arc Weld (*Metallic Arc*)										
(a)	1/16	Steel Kote	.10	.53	.040	.045						D. C. constant current 55 volt, 175 amp.
(b)	1/16	Steel Kote			Same							
(c)	1/16	Steel Kote			Same							Used 40 volt, 150 amp.
(d)	⅛	Steel Kote	.05	.20	.040	.036						
3		*Atomic Hydrogen*										
(a)	1/16	Strips from tube	.25	.65	.045	.05						Atomic Hydrogen Process. Single phase, 60 cycle, 80 volt, 18 amp., 1/16 tungsten electrodes.
(b)	1/16	Strips from tube			Same							
(c)	Unknown		.02	.08	.040	.013						

NOTE: Chemical Analysis of 1(a), (b), (c), (d), 2(a), 3(a) applies to original filler rod.
Chemical Analysis of 1(g), 2(d), 3(c) applies to deposited weld.

Both the 1-in. diameter and ½-in. diameter tubes used as the base metal in welding are what is known as mild carbon, cold rolled, seamless steel tubing made from 1025 steel, analysis as given under 3a of Table I. In order to insure uniformity of quality each length of tube (about 10 ft.) was first tested in tension before being accepted.

Test Specimens and Testing Machines:—The type of fatigue specimen used on the deposited metal is shown in Fig. 1a. It is standard for all metals in this laboratory. The ½-in. diameter welded tube specimen is shown in 1b, and the 1-in. diameter specimen is shown in Fig. 2.

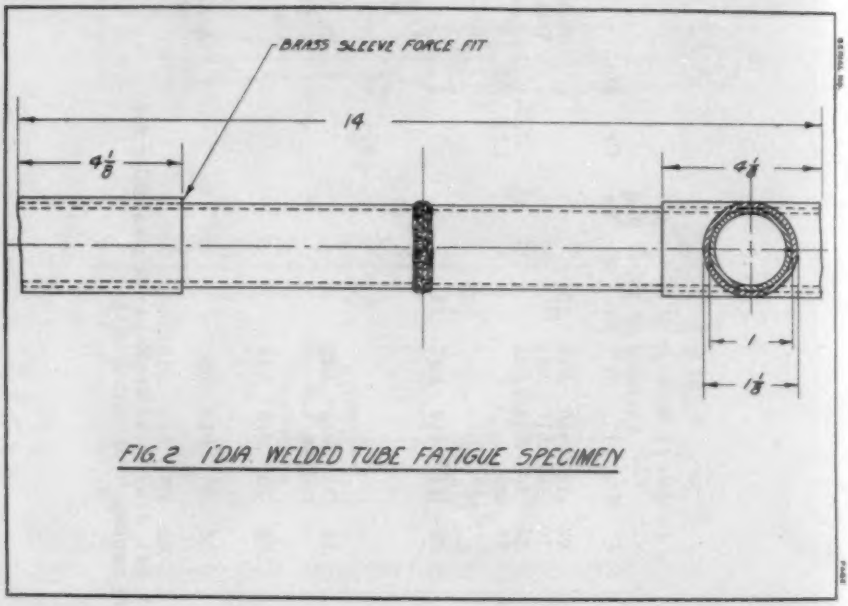


FIG. 2 1"DIA. WELDED TUBE FATIGUE SPECIMEN

The fatigue tests were made on the rotating beam type of machine. In this machine the specimen is subjected to flexural stresses which pass through a complete cycle from tension to compression equal in magnitude.

The deposited metal specimens and the ½-in. diameter tube specimens were made on the machine shown in Fig. 3. This machine was developed by the writer for the purpose of obtaining smoother running and more accurate tests than can be obtained on the long specimen types of machine sometimes referred to as the Farmer or Sandericker machine. In principle it is a rotating beam machine, but employs a specimen only about one-third the length of that formerly used. Without this short specimen it would not have been practical to make fatigue tests on the material representing the deposited weld because of the difficulty and expense in producing long sample bars. In the older machines the moment arm had to be laid off for each specimen tested. In the present ma-

chine the moment arm (distance from fulcrum pin to load yoke knife seat) is accurately and permanently established when the machine is built. This construction insures consistency between all tests run on the machine and permits of a more sensitive loading arrangement. The set-up is made at a great saving in time and there is no opportunity of deforming even the lightest specimens. A specially constructed driving mechanism and spindle insures unrestricted beam action which makes for greater accuracy. The length of the specimen is not fixed. It can be made anything within one inch longer or shorter than the standard shown in Fig. 1. The machine is plain bearing and runs silently and free from vibration. Twenty such machines operating at one time can scarcely be heard.

The 1-in. diameter tubes were tested in the machine shown in Fig. 4. It embodies the principles just discussed, but is much more robust in construction.

Determination of Endurance Limit:—The endurance limit was determined by the generally accepted method of determining sufficient points on the endurance curve to locate the stress at which the curve flattens out or becomes tangent to the horizontal axis. These endurance curves are shown in Figs. 5 to 8. The stresses are computed by the common beam formulas. The calculations are based upon the diameter and gage of the tube and not upon the size of the deposited metal in the weld.

RESULTS OF TESTS

Gas Welds:—The results of the fatigue tests taken from the endurance curves of Figs. 5 to 8 are combined with the tensile test results in Table II. Miscellaneous data on the properties of the original tubes, deposited welds, and cast steel are given in Table III.

The tensile strength of all the gas welded tubes falls between 56,500 lb. per square inch and 60,300 lb. per square inch. As all failures occurred outside the weld (1 in. from the weld) it can be said that no advantage in tensile strength is shown by either the Norway iron, low carbon steel, vanadium steel, or chromium molybdenum filler rods when welding this type of tubing. The location of the fracture is evidently due to softening of the tube by the heat of the welding torch and the increased cross section at the weld by the "piling up" of the deposited metal.

The highest endurance limit obtained on the gas welded 1-in. diameter tubes was 16,000 lb. per square inch for those welded with low carbon steel filler rod. This endurance limit is only 28 per cent of the tensile strength of such a welded joint. The vanadium filler rod did not improve the endurance limit, but actually gave a lower value. The Norway iron filler rod only gave an endurance limit of 13,000 lb. per square inch. In this case all failures occurred through the middle of the weld as shown in Fig. 10. The low carbon steel and vanadium steel filler rod speci-

mens did not fail in the weld. The failure was due to bending in the tube about 5/8 in. on each side of the weld. It is possible that by using stronger base metal tubes a higher endurance limit could be obtained for these two filler rods. This, however, does not apply to the Norway filler rod specimens which failed in the weld and showed upon examination to have good penetration.

The specimens welded with the chromium molybdenum filler rod gave a very low endurance limit (8000 lb. per square inch). This

TABLE II

Summary of Results

Type	Type of Welding	Tensile Strength	Endurance Limit	E. L. T. S.
1	Gas Welding			
(a)	Norway Iron Wire—McCook Field—1″ dia. tubes	60,300	13,000	.215
(b)	Low Carbon Wire—Air Reduction Co.—1″ dia. tubes	56,500	16,000	.283
(c)	Vanadium Wire—Air Reduction Co.—1″ dia, tubes	57,500	14,000	.243
(d)	Chrome-Molybdenum—McCook Field—1″ dia, tubes	59,400	8,000	.134
(e)	Norway Iron Wire—McCook Field—½″ dia. tubes	62,400	22,000	.353
(f)	Same—"Cleaned Up"—McCook Field—½″ dia. tubes	53,500	17,000	.318
(g)	Norway Iron Wire Deposited—McCook Field	50,500	24,000	.475
2	Arc Welding			
(a)	Steel Kote Wire—McCook Field—1″ dia. tubes	60,800	14,000	.230
(b)	Same—½″ dia. tubes	66,600	16,000	.240
(c)	Same—"Cleaned Up"	47,720	9,000	.189
(d)	Deposited Weld	62,500	24,000	.384
3	Atomic Hydrogen Welding			
(a)	Filler Rod same as tube..1″ dia. tubes	50,400	16,000	.317
(b)	Same—"Cleaned Up)	56,650	18,000	.318
(c)	Deposited Filler Rod	45,860	17,000	.371
4	Cast Steel	78,550	32,000	.408

TABLE III

Miscellaneous Data

	1″ Dia. Tubes	½″ Dia. Tubes	Deposited Gas Weld	Deposited Arc Weld	Cast Steel *
Tension					
Proportional Limit			22,000	41,050	23,800
Yield Point	55,000	55,000	30,640	53,900	43,540
Tensile Strength	75,000	63,000	50,500	62,500	78,550
Elongation	23.0	26.5	26.	1.5	5.7
Reduction of Area			45.		7.5
Modulus of Elasticity					30.6 x 10
Compression					
Proportional Limit					18,500
Yield Point					32,500
Tensile Strenth					108,500
Shear Strength					57,500
Torsion					
Proportional Limit					16,200
Modulus of Rupture					75,350
Modulus of Elasticity					11,920,000
Izod					5.0
Charpy					4.3
Endurance Limit		32,000	24,000	24,000	32,000

Note: *C .33; Mn .51; P .040; S .040

was not due to the type of filler rod but to poor welding as evidenced by lack of penetration of the weld. This is clearly shown in Fig. 9 from which it is seen that the weld is merely tacked to the outer surface of the tube with practically no fusion through the tube wall. This set of tests is valuable in demonstrating what may be expected from a poorly made weld in regard to resistance to repeated stresses.

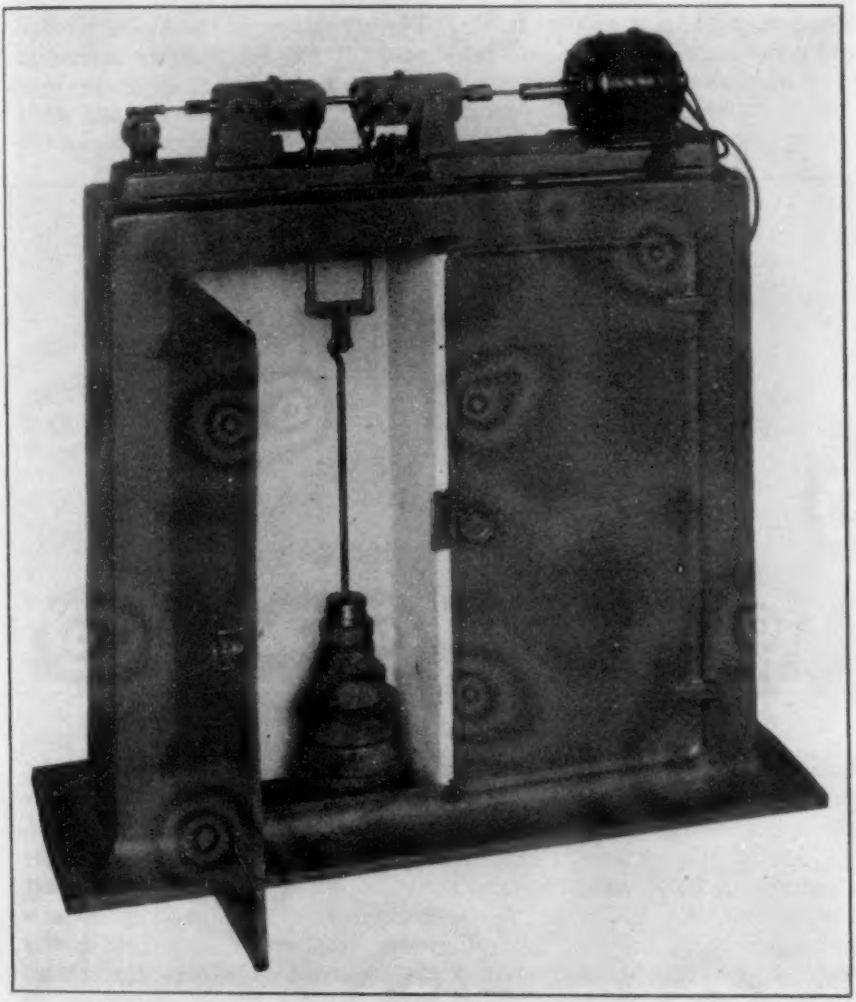


Fig. 3. Standard fatigue machine

It should be particularly noted, however, that the tensile strength of this weld was as good as the other welds and the fracture did not occur in the weld. Evidently the tensile test was unsuccessful in detecting the deficiency in the weld, whereas the fatigue test was particularly sensitive to this defect and demon-

strated its existence very pronouncedly. The value of the fatigue test is quite forcibly demonstrated here.

The ½-in. diameter tubes welded with Norway iron filler rod showed a 70 per cent increase in endurance limit (22,000) over the 1-in. diameter tubes welded in the same manner. The fracture did not occur in the weld this time, but in the tube. The microstructures of these two welds are shown in Figs. 11 and 14. Note the coarseness and remnants of dendritic structure in the fusion zone of the 1-in. diameter tubes. The structure of the ½-in. welded tube is more desirable and may account for its greater strength.

Examining the results of the tests on the ½-in. diameter gas welded tubes in which the excess weld was removed ("cleaned up") so as to reduce the deposited metal to the same dimensions as the

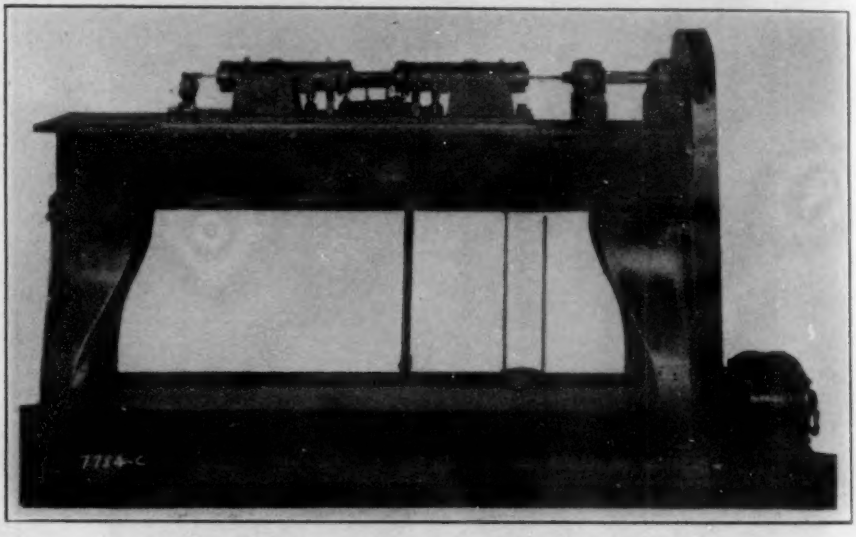


Fig. 4. Fatigue machine for one inch diameter tubes

tube, it is found that the endurance limit dropped to 17,000 lb. per square inch, which is 23 per cent less than for the tube before the weld is "cleaned up." The fracture occurs through the weld. Evidently the excess deposited metal in the previous tests strengthened the weld considerably. It is interesting to note that the endurance limit of the ½-in. diameter "cleaned up" specimens is higher than for the 1-in. diameter specimens with the excess weld still retained. Of course, as mentioned before, the ½-in. diameter specimens have the advantage of a better structure in the fusion zone. This may be due to the fact that the smaller specimen can be welded rapidly and kept at a more uniform heat than can be accomplished on the 1-in. diameter specimens. Consideration must also be given to the possibility of the presence of locally intensified stresses in the "piled up" weld due to the sudden change in section and also to residual stresses. This point will

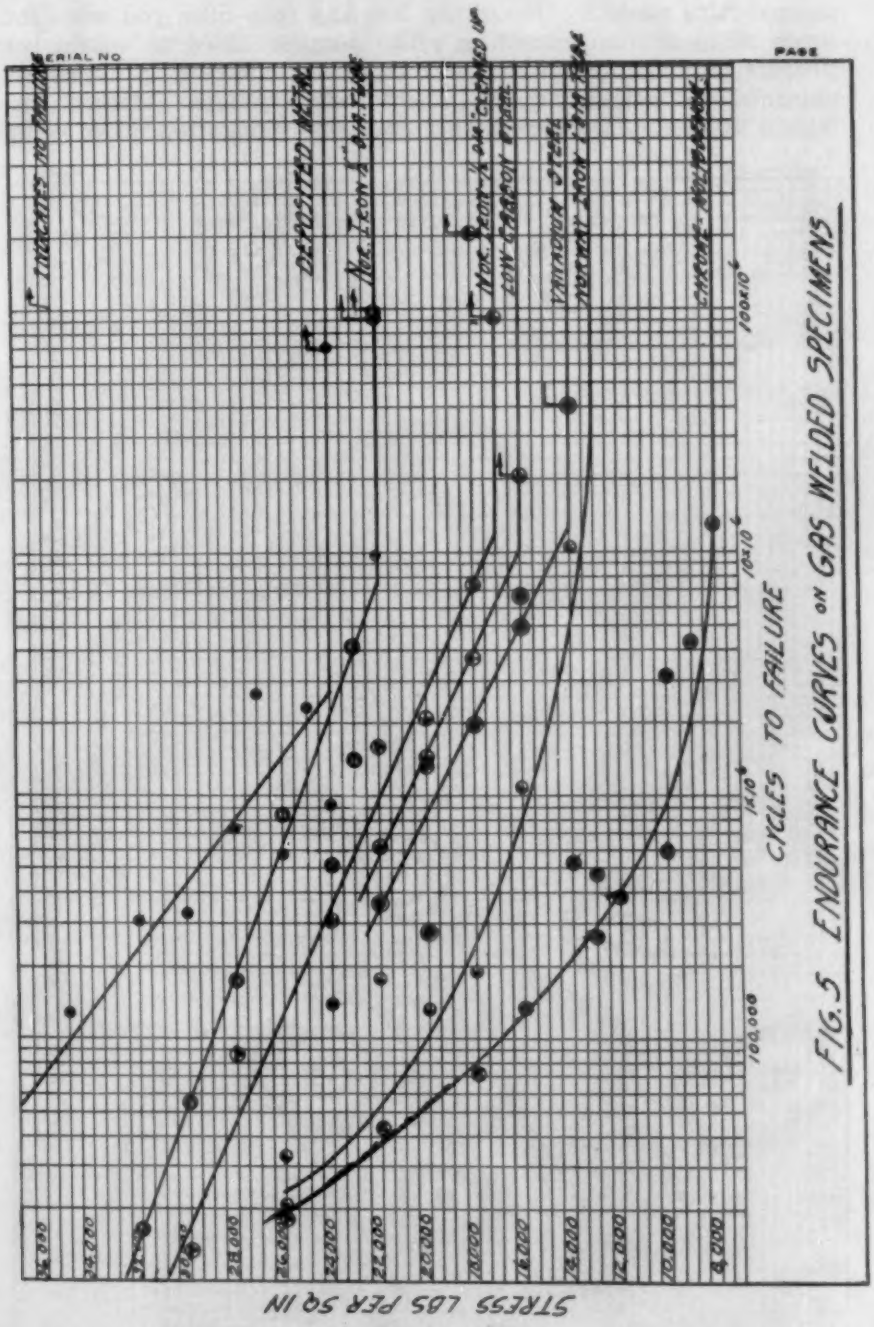


FIG. 5 ENDURANCE CURVES ON GAS WELDED SPECIMENS

be brought up again in connection with the atomic hydrogen welds. The last set of gas welding tests were on specimens taken from

sample bars made by depositing Norway iron filler rod with the torch as in ordinary welding. The purpose being to obtain the properties of the deposited metal itself to compare with the values obtained on welded joints. The tensile strength obtained was 50,500 lb. per square inch with 26 per cent elongation. The ½-in.

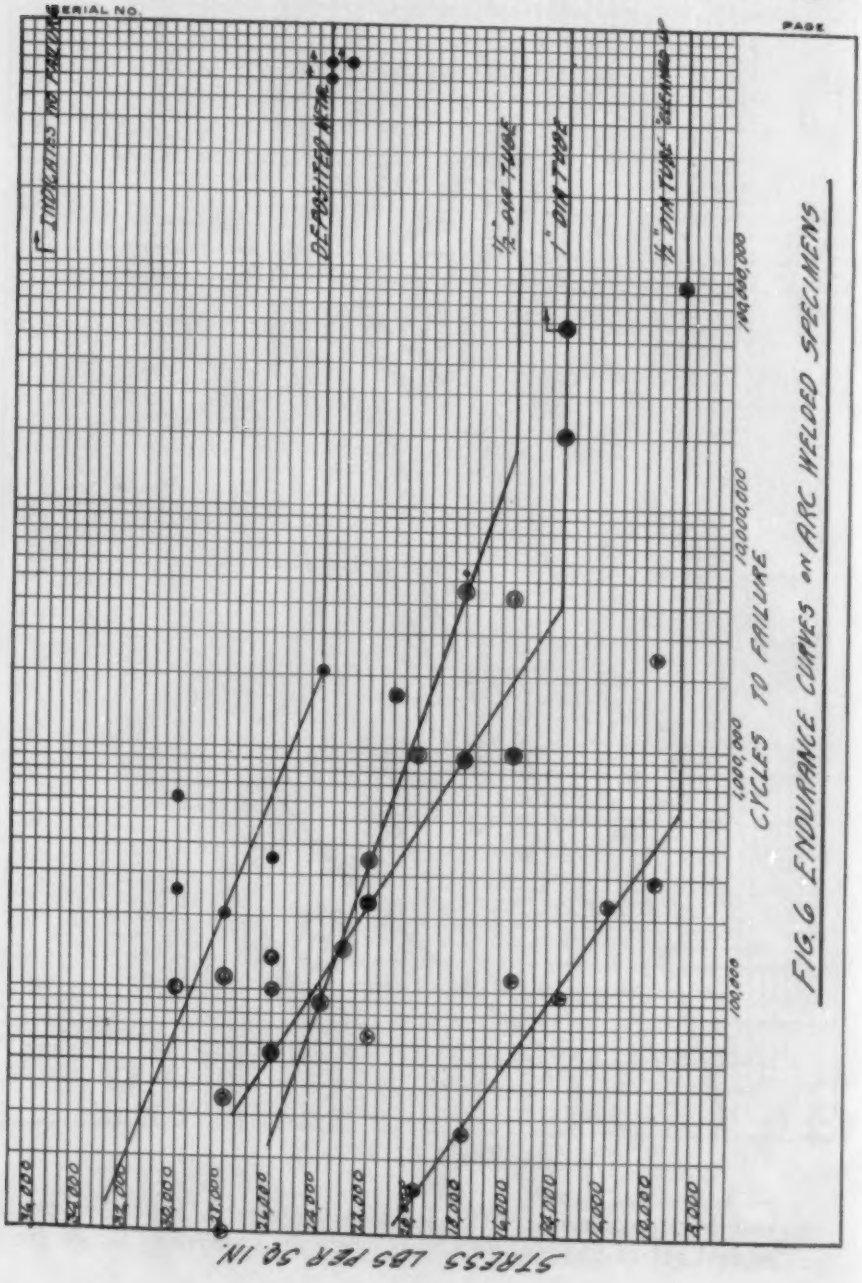


FIG. 6 ENDURANCE CURVES ON ARC WELDED SPECIMENS

"cleaned up" welded specimens gave a strength of 53,500 lb. per square inch. All other welds gave higher results, but allowance must be made for the increased area due to the "piled up" deposited metal, as all computations were made on a basis of tube

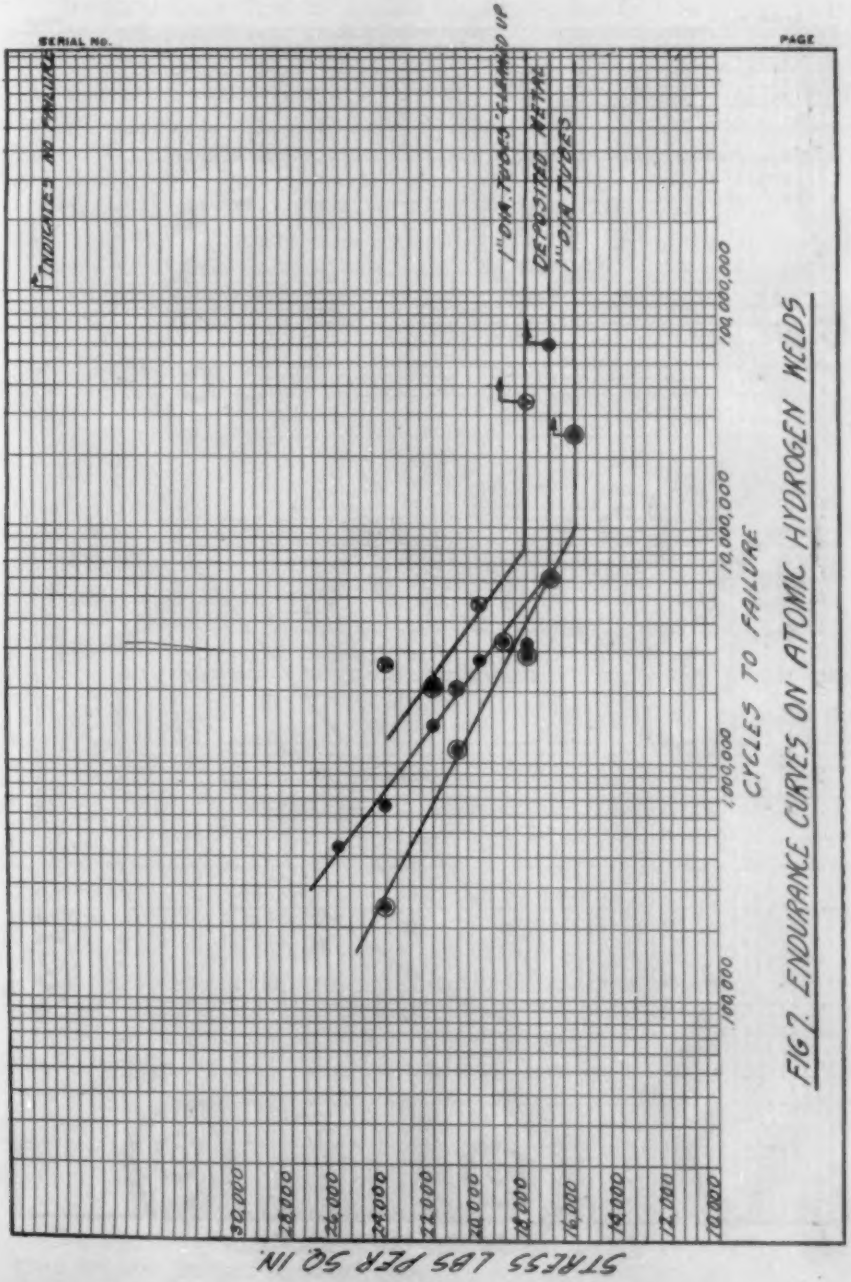


FIG 7. ENDURANCE CURVES ON ATOMIC HYDROGEN WELDS

dimensions. Furthermore, the tensile failures did not occur in the weld but in the tube.

The most valuable consideration is the relatively high endurance limit (24,000 lb. per square inch) of the deposited metal. This is 48 per cent of the tensile strength, which is an endurance ratio

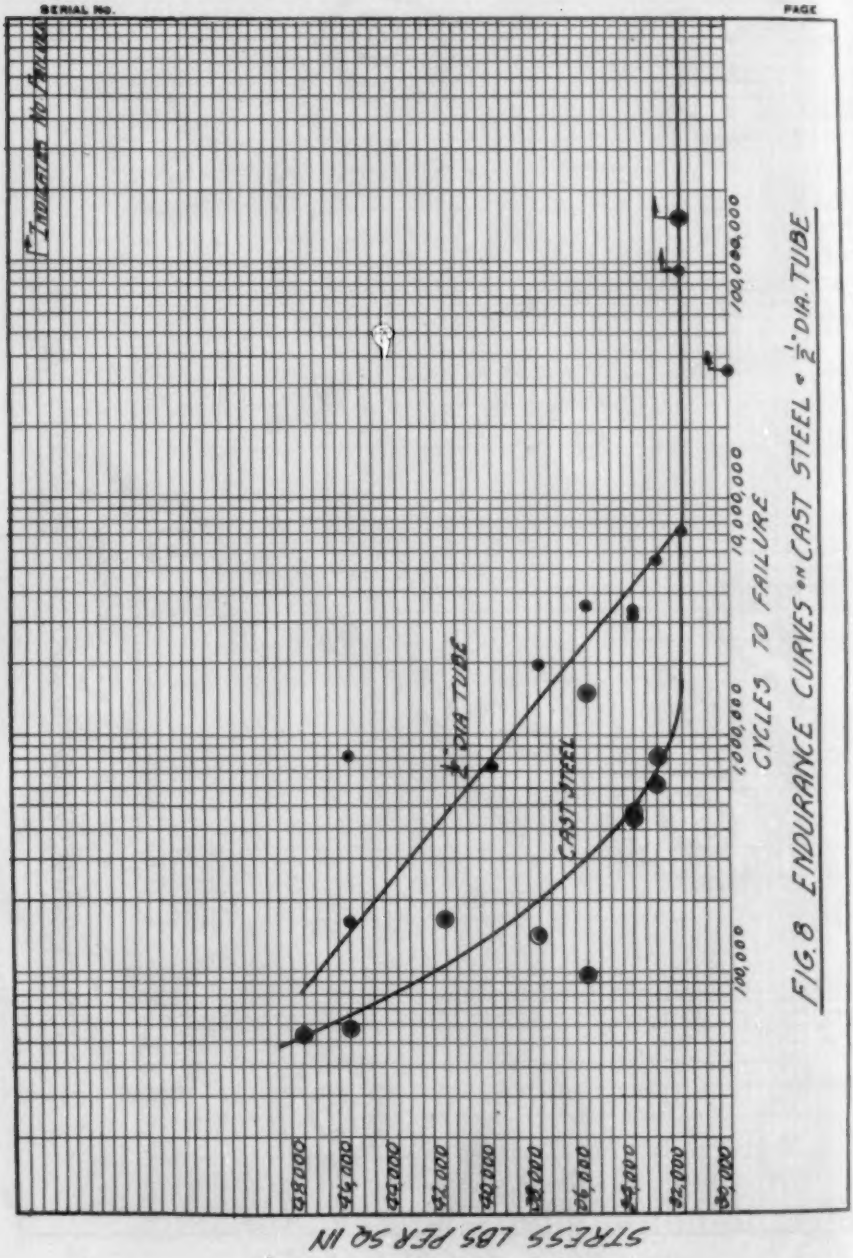
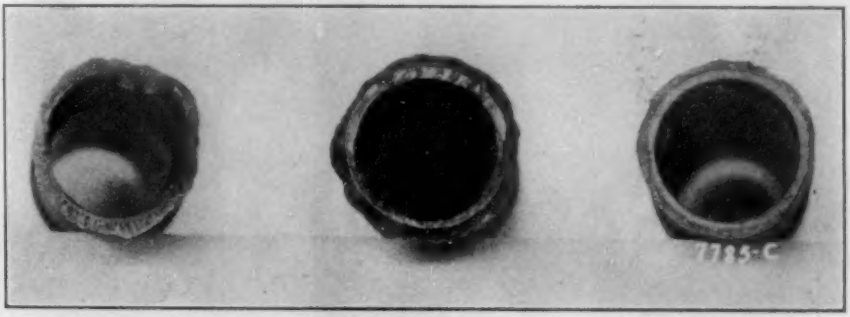


FIG. 8 ENDURANCE CURVES OF CAST STEEL ½" DIA. TUBE

exceeded by only a few steels. This would indicate that insofar as the deposited metal itself is concerned, the process of depositing or casting the metal by the gas method does not have any detrimental effect upon the resistance to repeated stresses.

The endurance limit of 24,000 lb. per square inch is better than found on any of the welded tubes. Ordinarily it might be expected that the "cleaned up" welded tubes would approach this value for the deposited metal because they are free from locally intensified stresses, the failures occurred in the weld, and the welds were good. They are, however, only 70 per cent as strong under repeated stresses.

Photomicrographs taken of both welds show some interesting differences. Compare the structure of the deposited metal in Fig. 17 with that in the fusion zone of Fig. 14. The structure in Fig. 14 is due to more rapid cooling caused by the thinness of the weld metal section and the ability of the adjacent steel tube to



a
Through weld
Good bond

b
Through tube

c
Through weld
Poor fusion
Chromium molybdenum weld

Fig. 9. Types of fatigue fractures in one inch diameter tubes

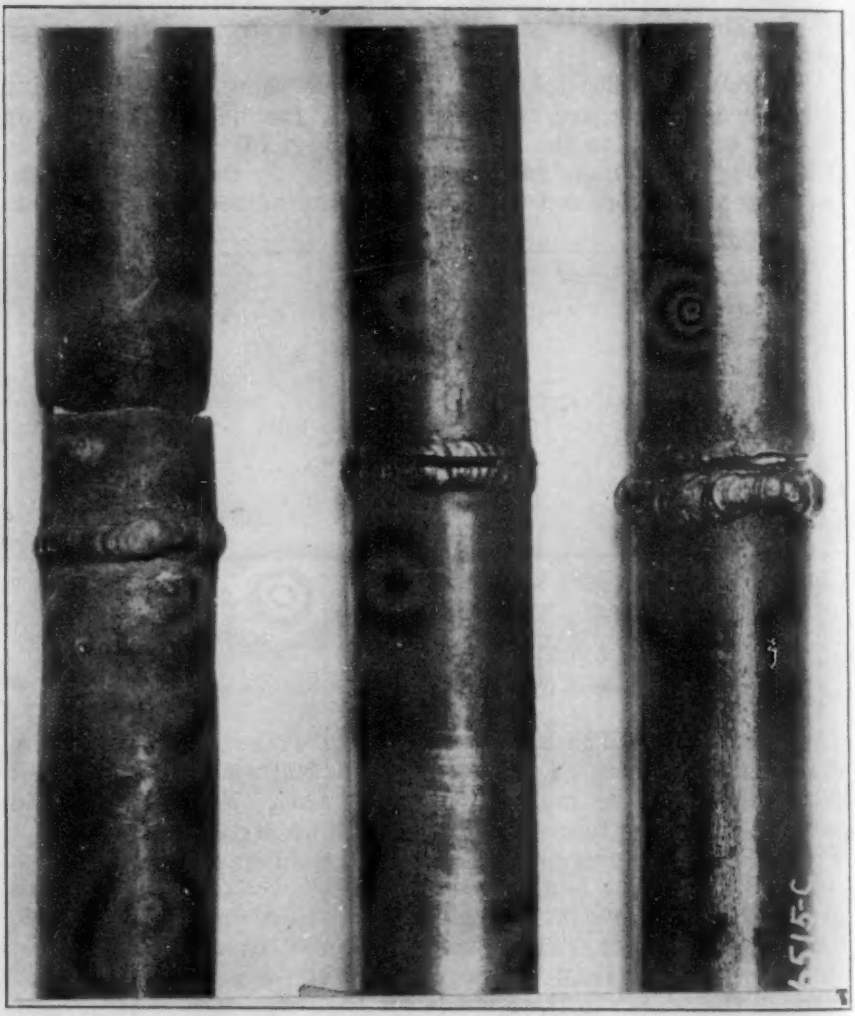
draw the heat. The structure in Fig. 17 represents a ¾-in. diameter solid mass of the metal. The test specimen is turned from the center, the more slowly cooled part. Evidently then, in welding thin gage tubes, we do not obtain a structure throughout which is representative of our deposited weld specimens.

Arc Welds:—The 1-in. diameter tubes showed a tensile strength practically the same as the gas welded tube and an endurance limit slightly better. The tension fractures occurred in the tube, while the fatigue fractures occurred at the edge of the weld or through the weld. In these welds the bead was such as to develop an abrupt change in section setting up locally intensified stresses which is believed to have been the cause of the location of the fatigue fractures. Local heating also contributed to some extent.

The ½-in. diameter tubes gave an endurance limit of not better than 16,000 lb. per square inch. The exact location is not quite

clear, but assuming that the knee of the endurance curve occurs at or before ten million cycles (as obtains on all the other weld tests) this value is satisfactory. It again seems as if the sudden change in section at the weld has considerable influence in forcing the fracture at the edge of the weld and consequently upon the value for the endurance limit.

The ½-in. diameter tubes when "cleaned up" at the weld gave the very low endurance limit of 9000 lb. per square inch. This



a
Tension fracture
Outside weld
Gas weld

b
Fatigue fracture
In weld
Gas weld-Norway iron
Filler rod

c
Fatigue fracture
Edge of weld
Arc weld

Fig. 10. Locations of fractures

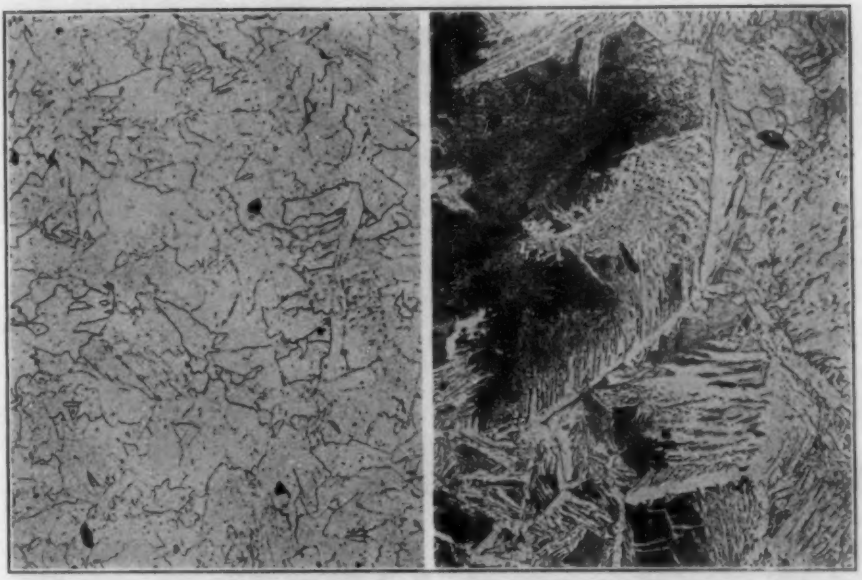


Fig. 11a. 100×
At weld

Fig. 11b. 100×
Transition Zone

Gas weld one inch diameter tube, Norway iron filler rod

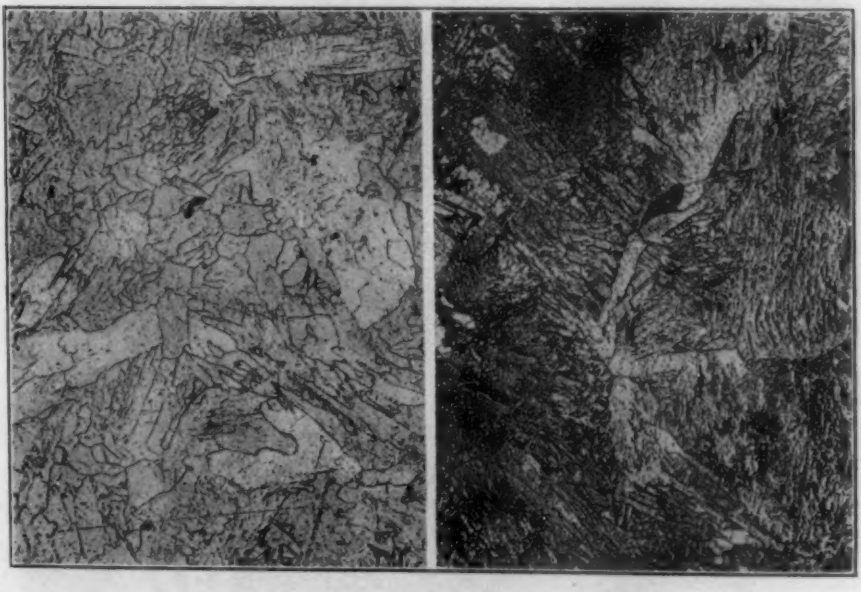


Fig. 12a. 100×
In weld

Fig. 12b. 100×
Transition Zone

Gas weld one inch diameter tubes, low carbon steel filler rod

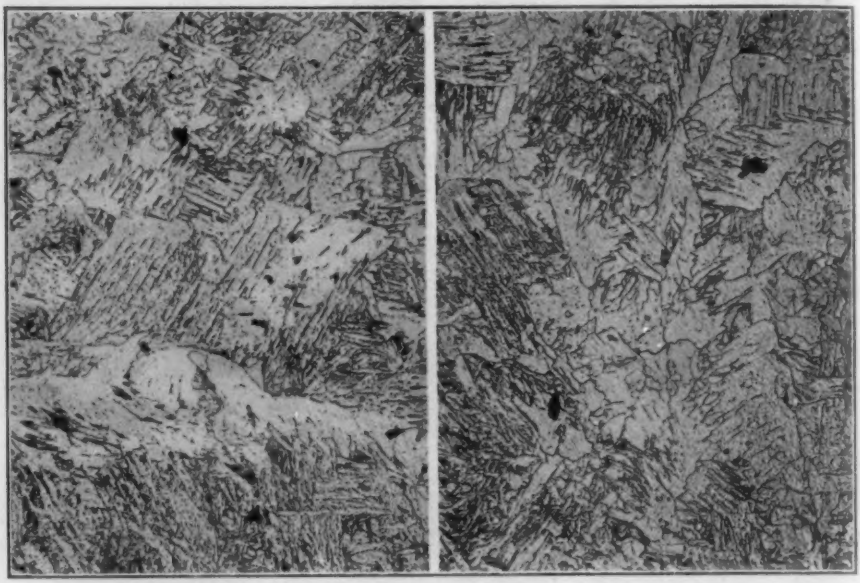


Fig. 13a. 100×
In weld

Fig. 13b. 100×
Transition Zone

Gas weld one inch diameter tube Vanadium steel filler rod

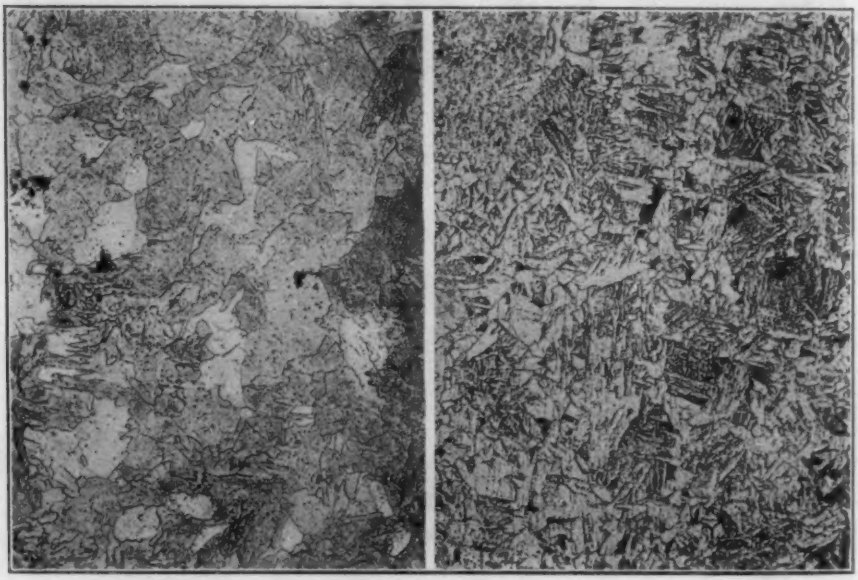


Fig. 14a. 100×
In weld

Fig. 14b. 100×
Transition Zone

Gas weld one-half inch diameter tube, Norway iron filler rod

was traced to poor fusion. Examination of the fatigue fractures under binoculars showed that the fracture occurred at the weld in the fusion zone. There was very poor fusion between the tube and the weld, and many blow holes existed in the weld. On every specimen tested was found spots where there had been no bond at all. The original wall of the tube was clearly exposed. In some cases 30 per cent of the cross section of the tube showed no bond. In no case was it less than 7 per cent. Attention is again directed to the sensitivity of the fatigue test to poor fusion. It is suggested that the fatigue test on "cleaned up" welds may be an effective means of studying the quality of various types of welds.

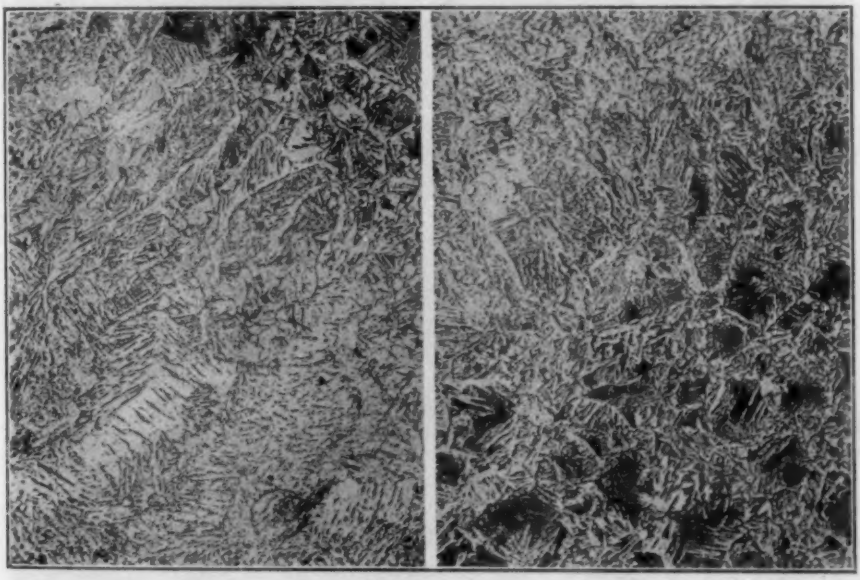


Fig. 15a. 100×
In weld

Fig. 15b. 100×
Transition Zone

Arc weld one inch diameter tube, steel kote filler rod

The specimens made from the metal deposited by the arc process gave a tensile strength of 62,500 lb. per square inch and 1.5 per cent elongation. High in strength but very brittle. The endurance limit was 24,000 lb. per square inch, the same as for the gas weld. This brings its endurance ratio down to 38 per cent. The electrically deposited metal evidently was not quite as resistant to failure by fatigue as the gas deposited metal.

In making the photomicrograph for the structure of the deposited metal, it was found that two structures existed as shown in Fig. 17a. The etched specimen was then photographed at a few diameters magnification as shown in Fig. 18. It will be remembered that the pad of deposited metal was made up by the "beading" process rather than by puddling. It is believed that this

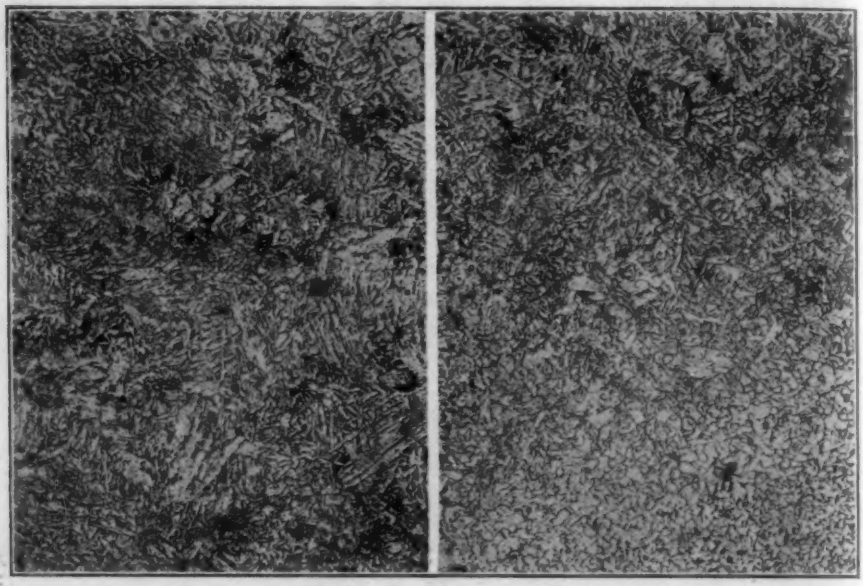


Fig. 16a. 100×
In weld

Fig. 16b. 100×
Transition Zone

Arc weld half-inch diameter tube, steel kote filler rod

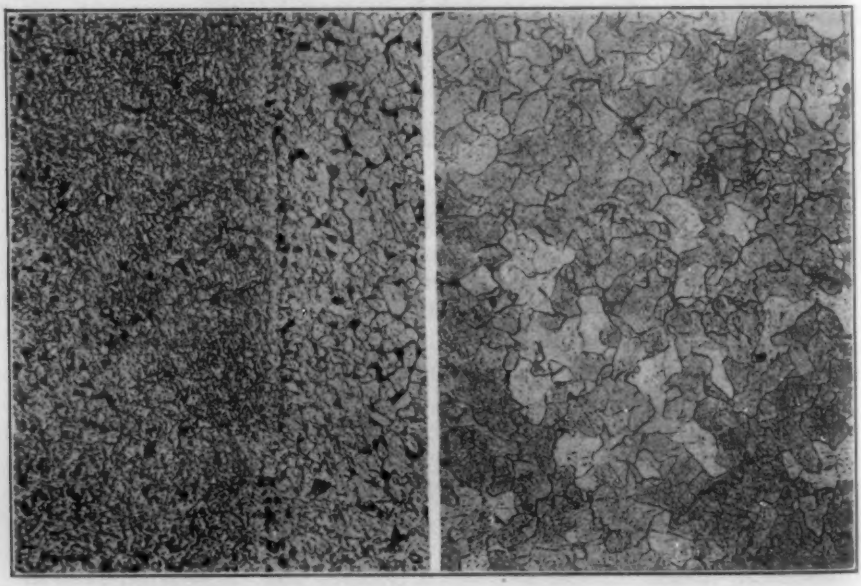


Fig. 17a. 100×
Arc weld. Steel kote filler rod. Deposited metal specimen

Fig. 17b. 100×
Gas weld. Norway iron filler rod. Deposited metal specimen

contrast in structure indicates the zones of two adjacent beads. The heat of the last one applied modifies the structure of the adjacent beads to make this contrast. This did not occur on the gas weld because the metal is "puddled."

The ½-in. diameter tubes show a finer grain than the 1-in. diameter tubes at the fusion zone. Both should be compared with the structure of the deposited weld.

Atomic Hydrogen Process:—The third method of welding investigated was the atomic hydrogen process developed by the General Electric Company. The principle of this method is to prevent the formation of oxides and nitrides by welding in a flame of atomic hydrogen. The filler rod used was made from strips of the tube itself. These welds gave a tensile strength of 50,400 lb. per square inch which is less than any of the other 1-in. diameter welded tubes. The failures occurred 1¼ in. from the weld. This

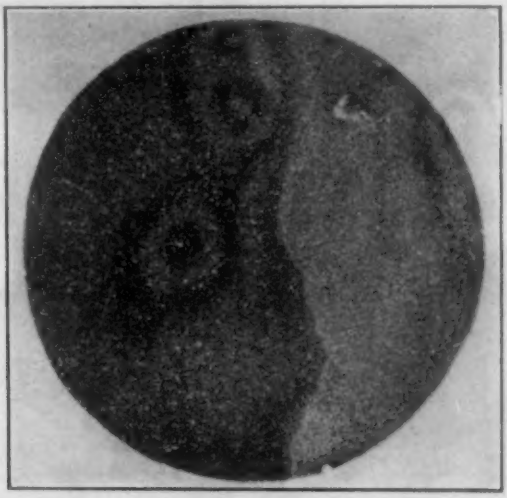


Fig. 18. Effect of building up by beading

method of welding evidently softened the tube more than either the gas or arc methods. The endurance limit was 16,000 lb. per square inch with the fracture occurring in some cases at the edge of the weld but usually about ¼-in. away from the weld. When the weld was "cleaned up" an endurance limit of 18,000 lb. per square inch was obtained, the fracture occurring in the weld. It would appear from these results that the "piled up" weld, due to the sudden change in the section produces locally intensified stresses which weaken the tube under repeated stresses.

The deposited weld specimens were not made from the same filler rod as used on the tubes. It was evidently an iron filler rod as indicated by the analysis in Table I. It gave a tensile strength of 45,860 lb. per square inch, and an endurance limit of 17,000 lb.

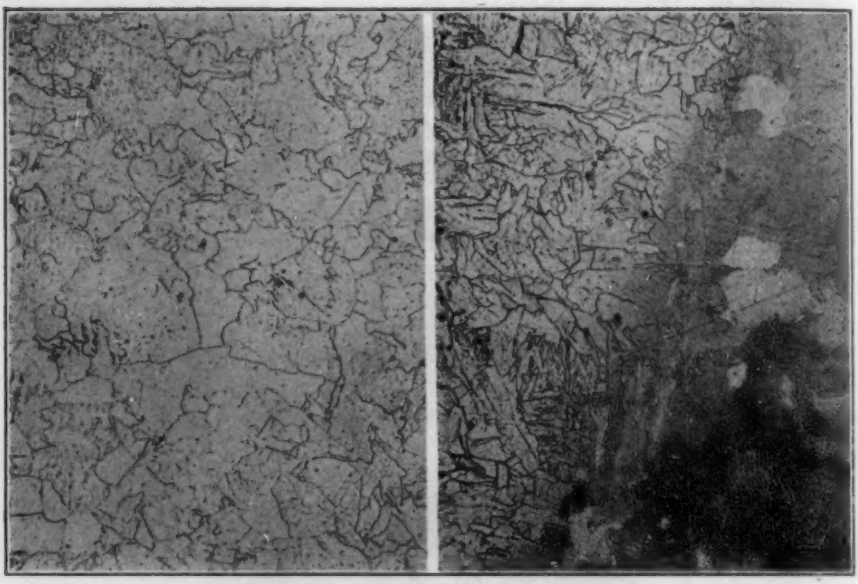


Fig. 19a. 100×
In weld

Fig. 19b. 100×
Transition Zone

Atomic hydrogen weld. One inch diameter tubes. Filler rod same as in tubes

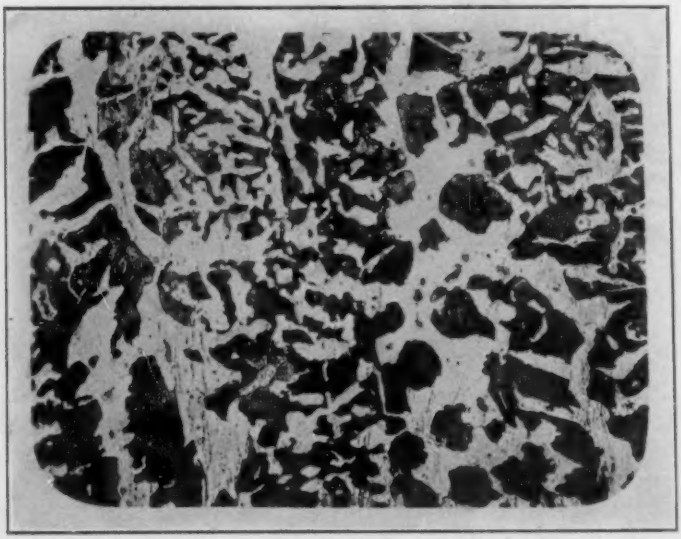


Fig. 20. 100×
Transverse cast steel

per square inch. This is an endurance ratio of 37 per cent, about the same as the deposited arc weld.

Cast Steel Tests:—It was desired to know whether deposited

steel filler rod could be assumed to possess the same general properties of cast steel, or whether the method of casting as applied in welding had some deleterious effect upon the metal. Specimens were prepared from bars of cast steel 2 in. x 2 in. x 18 in. with properties and analysis as given in Table III. Briefly, a tensile strength of 78,550 lb. per square inch and an endurance limit of 32,000 lb. per square inch were obtained. This gives an endurance ratio of 41 per cent, which is slightly better than the arc weld deposit and atomic hydrogen deposit, but not as good as the gas weld deposit. The gas weld deposit, however, is iron which is known to give a high endurance ratio. The cast steel contained

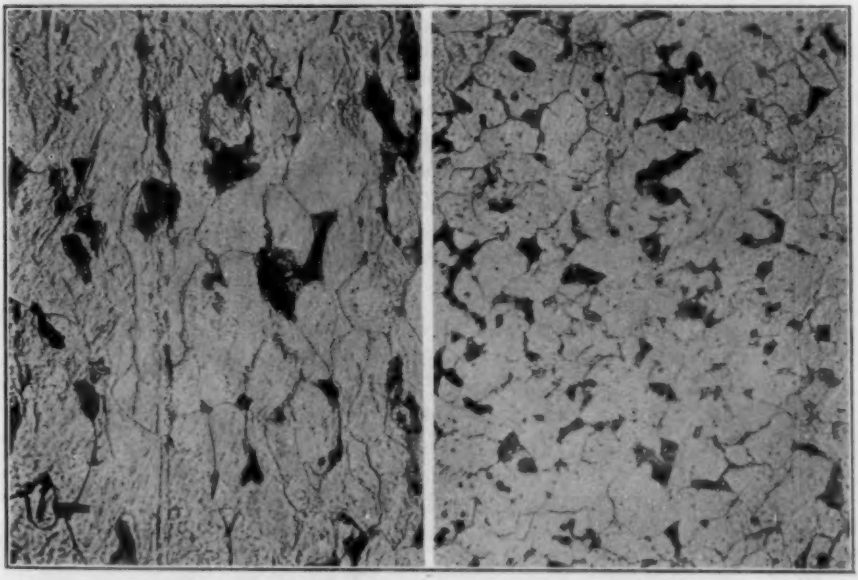


Fig. 21a. 500×
Longitudinal

Fig. 21b. 500×
Transverse

Steel tube half inch diameter

.33 carbon and the electric weld deposit .10 carbon. On the other hand, the atomic hydrogen weld was also iron, but did not give as good a ratio as the cast steel or the gas welded iron. It cannot be said then, that any of these welding processes produces a deposit much more susceptible to fatigue than cast steel. Furthermore, one type of welding is decidedly superior than cast steel in fatigue resistance. Very poor welding which develops a metal filled with cavities is, of course, excepted, as would be poor cast steel or even poor wrought steel.

Existence of Endurance Limit:—One of the drawbacks to the general acceptance of welding has been a feeling among engineers that the metal deposited under such conditions possessed some

undesirable property akin to brittleness which would determine its ultimate failure if long subjected to repeated stresses. The writer made a special effort to obtain some data upon the action of welded metal under a very large number of repetitions of stress to determine whether a metal solidifying under these conditions really possessed such a property as an endurance limit similar to that found in wrought ferrous metals. It was found that the deposited metal does have an endurance limit just as wrought ferrous metals do. The evidence is given in Figs. 5 to 7 which show the endurance tests on the deposited gas and arc welds. The arc weld tests are very convincing. Two tests at a stress of 24,000 lb. per square inch have completed over 600 million and 700 million cycles without failing. One test at 23,000 lb. per square inch has completed 700 million cycles without failing. All tests are still in progress. These tests demonstrate that the deposited weld metal is not inherently weak under stresses repeated an enormous number of times. The 700 million cycles of stress covered in these tests are equivalent to, and in many cases in excess of, the number of cycles encountered during the life of a machine or structure.

SUMMARY

Although the tensile efficiency of the welded tubes was better than 75 per cent, the fatigue strength was as low as 13 per cent and never higher than 35 per cent of the tensile strength of the weld.

Poor fusion has a drastic effect upon the resistance of the weld to repeated stresses. Poor fusion may not be detected by the tension test, but is detected by the fatigue test.

The ½-in. diameter welded tubes showed a better resistance to fatigue than the 1-in. diameter tubes, probably because they can be welded more uniformly.

The endurance limit developed by specimens from solid deposits of weld could not be equaled by the welded tubes. This is probably due to a difference in structure caused by the more rapid cooling of the relatively thin weld metal joining the tubes.

The deposited gas weld showed an endurance ratio as good as found on most steels. The deposited arc weld and atomic hydrogen weld were somewhat lower.

The "piling up" of the weld may operate to lower the resistance to repeated stresses due to locally intensified stresses set up by the sudden change in cross section.

Long time fatigue tests show that the deposited metal has a definite endurance limit just as is found in steels.

Replacing Castings by Welded Steel Parts*

J. F. LINCOLN†

Arc welding is a comparatively old science—that is, the first patents were taken out in connection with this more than thirty years ago. However, its use commercially, on a large scale, is comparatively recent.

Undoubtedly the repair of the interned German ships in the harbors of the United States, during the late war, brought arc welding to the attention of the American people a good deal more strongly than any other application which has ever been made. The repair of the German ships as we see it now was a comparatively simple operation, and while it undoubtedly saved a considerable amount of money and time for the American Government and increased materially the efficiency of the American intervention in the war, yet the actual use of welding in this case and in all other repair cases must be of secondary importance.

While the use of arc welding for repairs undoubtedly saves this country in excess of one hundred million dollars per year, by far its greatest value in the future is going to be in the replacement of riveted steel and castings with arc welded structural steel—the fundamental reason why this replacement will come is twofold:

In the first place, compared to rivets arc welded steel will give the full strength of the joint while rivets will give from 50 to 80 per cent of the sheet strength when the riveted joint is made in the usual commercial manner. This means, therefore, any structure which is made of riveted steel and depends on the strength of the joint for its efficiency, must have from 30 to 100 per cent more steel in it than will be necessary if an arc welded joint were used. What this amounts to in the aggregate is a stupendous sum, as can be well appreciated.

However, there is still another application which is of very much greater importance even than that—this is the application of arc welded steel to the replacement of castings of all kinds. The fundamental principles involved here are as follows:

Cast iron has a tensile strength of approximately 10,000 pounds per square inch.

Welded steel approximately 50,000 pounds.

Cast iron has a modulus of elasticity of 12,000,000.

Steel has a modulus of elasticity of 30,000,000.

Castings have an average cost per pound of 6c.

Rolled steel has an average cost per pound of 2c.

The factor of safety necessary for the same degree of safety will be half as great with steel as with cast iron. Therefore, if a pressure vessel is to be made of any kind in which the strength of the shell is the limiting factor if made from cast iron, it will cost

*To be presented at the Annual Meeting, A. W. S., April, 1927.
†Vice-president, Lincoln Electric Company.

for the same degree of safety approximately twenty-five times as much as if made from rolled steel; if a base or any structure which is used for resisting bending is to be made, the cost will be approximately 15 per cent as much if made from structural steel as if made from castings.

When the total amount of this saving is considered, it is easy to see that the amounts involved run into enormous sums even to the American people, who are in the habit of speaking glibly of billions.

It might be well at this time to consider the problems which are involved in taking advantage of these fundamental principles. It is quite evident that if the job were as simple as merely replacing one metal with another that there would be no doubt about its immediate acceptance. The proposition is not nearly as simple

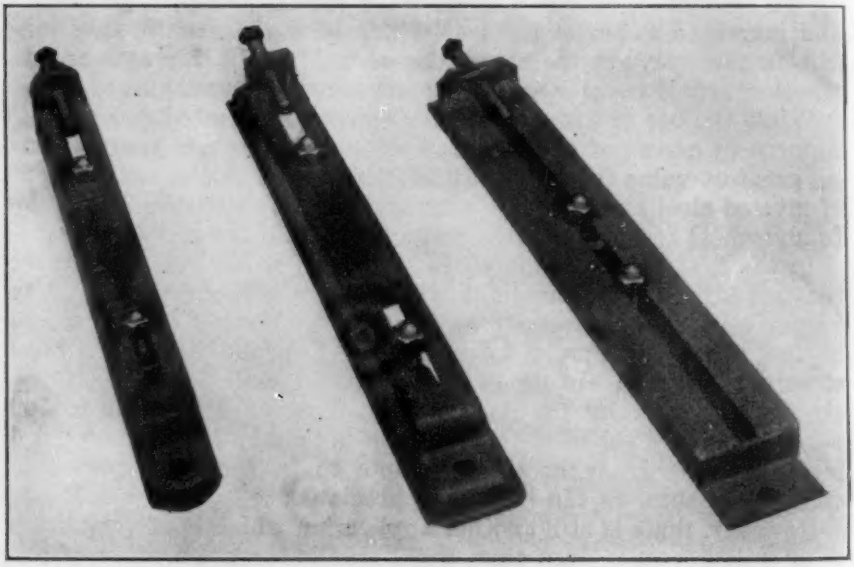


Fig. 1. Motor base rails; at left and center casting, and at right welded steel construction

as that—one great virtue of the casting is the fact that it can be made into any shape with very great ease. However, rolled steel must of necessity (from its very method of manufacture) be made in certain definite shapes and those only.

These shapes can, of course, be made the most efficient for doing the kind of work they are designed to do, and if these shapes can be adopted directly without change, they will do any work better because of this shape than would be possible with most cast shapes entirely aside from their greater strength and stiffness.

However, there are a great many cases where it is necessary to make a structure which is radically different from the shapes which can be got directly from the steel mills, therefore, the

possibilities of the designing engineer in redesigning cast structures to the use of welded steel, is one of enormous importance. In fact, the designer of the future who can apply this new tool to best advantage will be an outstanding engineer.

The importance of this seems so great to the company with which the writer is connected that they have given three prizes of $10,000, $5,000 and $2,500 respectively for the best application of arc welding to the redesign of present-day structures, hoping that this will get the brains of the country to considering this proposition more closely, more intelligently and more thoroughly, so that the savings which this redesign will give may be obtained in the shortest possible time.

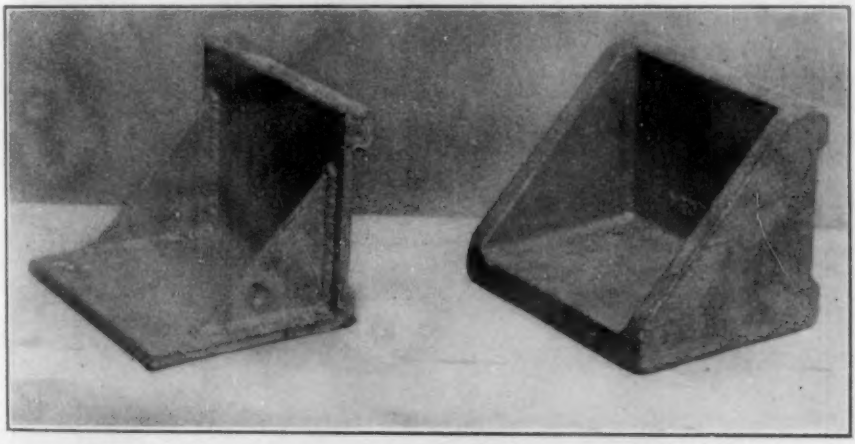


Fig. 2. At left, support made from welded steel parts; at right, casting

Entirely aside from that, however, there is another very definite attitude of mind which is holding back the universal acceptance of arc welding as an economical producing tool, and that is the fact that habit so largely controls our minds. Mankind in general accepts without question the theory that if a precedent has been established, it must of necessity be right and should continue to be followed. Of course, all laws are based on this fundamental principle, and perhaps that is one reason why there is so much dissatisfaction with law, but it should appear that the engineer would be the first to reject tradition when it is self-evident that tradition is wrong in the light of present-day development.

I think it is safe to say there is no best manufacturing method and no best manufacturing tool which is today the same as it was fifteen years ago. I think it also safe to say that there are very few which are the best today that are the same now as they were five years ago—I think it is safe to say, also, that any manufacturing concern who is today manufacturing any product exactly the same as that of six months ago is not pursuing the best possible way, and if any product has not been entirely redesigned from

what it was five years ago, probably the concern manufacturing it is rapidly losing ground.

In spite of the tendency to go slowly on a change as radical as eliminating castings and rivets with welding, yet there has been enormous progress in the application already. At the present time most simple bases of motor generator sets, motor-driven pumps, and work of a similar nature has been redesigned to the use of structural steel instead of the former cast iron. Some buildings have been erected this way—some bridges have also been made of arc welded steel. In these cases the saving has ranged from 85 per cent of its previous cast iron or riveted steel cost, to 15 to 20 per cent saving over the original cost.

Other examples of this same fundamental scheme of applying arc welded steel in place of castings, are the following:

In the case of the rotor spider for an electric motor:

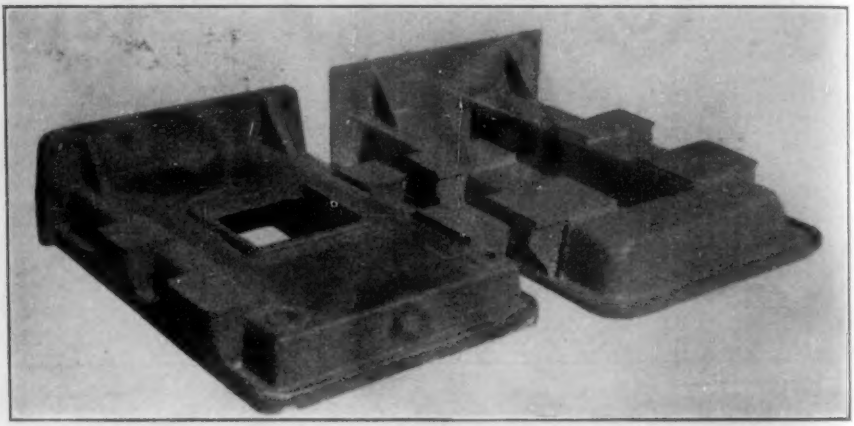


Fig. 3. Elevator base. At left, casting; at right, welded steel base

Cast Iron, wt. 70¼ lbs.		*Arc Welded Steel, wt. 43¼ lbs.*	
Cost of cast iron casting	$6.75	Cost of rolled steel	$1.28
Labor cost	2.94	Labor cost	4.37
Total	$9.69	Total	$5.65

Another case is that of the end ring for a motor which heretofore has always been made of cast iron. The comparative costs follow:

Cast Iron		*Arc Welded Steel*	
Cost of rough casting	$2.89	Cost of rolled steel	$1.126
Labor cost	.195	Labor cost	.407
Total	$3.085	Total	$1.533

Another case is a motor base rail which heretofore has always been made of cast iron—the comparative costs follow:

Cast Iron, wt. 77 lbs.		*Arc Welded Steel, wt. 66 lbs.*	
Cost of rough casting	$4.992	Cost of rolled steel	$1.536
Labor cost	.117	Labor cost	.617
Total	$5.109	Total	$2.153

Another interesting application is that of the motor extension for an elevator base—this has heretofore always been made of cast iron. The same base made of welded steel is shown with its comparative cost:

	Weight	*Cost*
Cast Iron	184 lbs.	$11.04
Arc Welded Steel	109 lbs.	5.45

A wheel for a shop truck which heretofore has always been made of castings has been replaced in the case of a certain truck for the use of arc welded steel—in this case a section of T stock is bent into a circle, welded, a piece of pipe used for the hub, and flat stock for the spokes. The comparative costs follow:

Arc Welded Steel, wt. 12.5 lbs.		*Cast Iron, wt. 25 lbs.*	
Cost of rolled steel	.35	Cost of rough casting	$1.75
Labor cost	.33	Labor cost	.10
Total	.68	Total	$1.85

Some other parts which have a more or less wide application (since they are indicative of what can be done in the redesign of any part from cast iron to steel) are shown below.

In one case a 12-in. pulley, which is generally made cast, is replaced by a steel section:

Cast Iron, wt. 79 lbs.		*Steel, wt. 40 lbs.*	
Material	$7.90	Material	$1.20
Labor	2.99	Labor	1.85
Total	$10.89	Total	$3.05

In the case of the wall box shown, the comparison is as follows:

Cast Iron, wt. 35 lbs—$2.10	*Steel, wt. 14 lbs.*	
	Material	.42
	Labor	.30
	Total	.72

In the case of the support as shown, which is an example similar to those used in endless other applications of a like nature, the comparison is as follows:

Cast Iron, wt. 27 lbs.—$2.27	*Steel, wt. 14 lbs.*	
	Material	.42
	Labor	.23
	Total	.65

It will be noted that in no case is the overhead included in these costs. The reason this is not done is not because of the fact that it will change the final result, but because of the fact that overhead is a widely varying quantity, and overhead in its amount is, to a considerable extent, controlled by the amount of inventory, as inventory, depreciation, storage, and interest charges are invariably a part of the overhead.

It is self-evident that in general the labor cost is higher with arc welded steel replacing cast iron than with the original casting. Therefore, if overhead were included with its usual percentage, the ratio would be more favorable to cast iron, although still the arc welded steel would be very much cheaper. However, the arc

welded steel has one very great advantage over cast iron and that is that the inventory cost necessary for certain production will be enormously decreased. Therefore, one item of inventory will be decreased by this substitution. Also, the item of patterns, pattern storage, and repair will be entirely eliminated, which also will very greatly affect inventory.

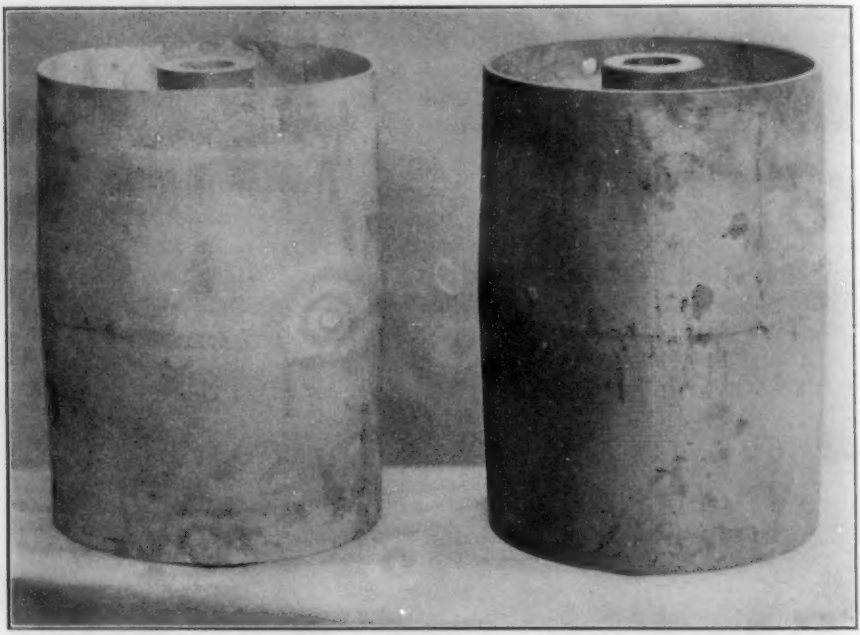


Fig. 4. Twelve inch pulley. At left, welded steel and at right, casting

In general I think it is safe to say that the items which would reduce overhead would be largely balanced by the increase necessary because of the increased labor cost, so that the total actual figure, including overhead, in both cases would probably, as an average, balance. This is an estimate only, but indicates the experience that the company with which the author is identified has found to be true.

Much work must still be done in getting the best shapes and the best method of applying these shapes to the work in hand. In the case of buildings, there is still much work to be done in the design of the joint for most efficient application of the new process, also for the methods of erection, which become a very serious problem in arriving at the most economical method possible.

Another application which is just beginning is the manufacture of pipe by this new process. The advantage here is in the fact that the diameter can be made anything that is required; the thickness of the wall can be made anything required; the material going into the pipe can have a very wide range of specification

and still the cost would be probably not more than two-thirds of the cost of tube mill or riveted pipe. Because of this, pipe lines in the future will undoubtedly be welded in the making of each section itself as well as welding the sections together in the field.

At the present time there has been completed a number of water lines, some of them running up close to one hundred miles in length, and in diameters up close to six feet. Yet I think it is safe to say that the average engineer now would still put in riveted or lock bar pipe because that is what has always been put in, in spite of the fact that the new welded scheme will save much money and make a very much more efficient line.

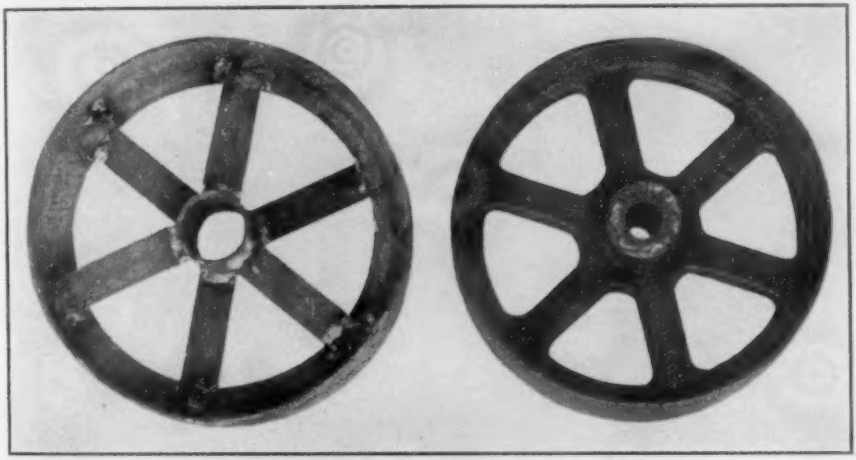


Fig. 5. Wheel for shop truck. At left, welded steel; at right, casting

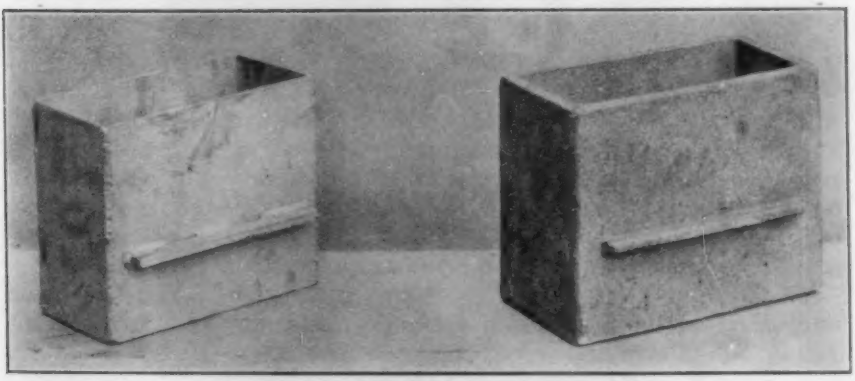


Fig. 6. Wall box. At left, welded steel box; at right, casting

The same attitude of mind is probably best illustrated by the present practice in connection with high pressure superheated steam. The steam must be generated in boilers which are riveted (because State law eliminates any other process than riveting

being used in a boiler shell), however, the superheater cannot be made tight by rivets because of the very much higher temperature at which it is operated. Also, the steam piping running from the superheater to the turbines cannot be made tight except by arc welding. Therefore, we have the rather anomalous situation of the boiler generating the steam being riveted, and the superheater and piping operating at exactly the same pressure but higher temperature, being welded.

Another illustration of the same rather unique point of view is shown in the common locomotive. The Interstate Commerce Commission allows very wide latitude in the case of arc welding on

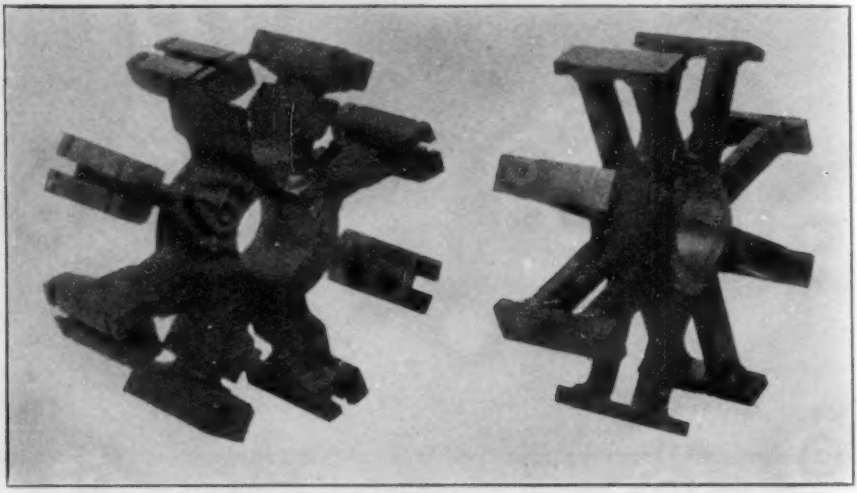


Fig. 7. At right, welded rotor spider; at left casting

locomotives, and there is practically no locomotive in existence at the present time which has not a very considerable amount of arc welding used both in its manufacture and repair. As is well known, it carries 200 pounds steam pressure, is hand fired, and is racked over the rails at sixty miles per hour. Yet under these conditions very few cases of failure of weld in a locomotive have ever occurred, and arc welding has, in the opinion of many railroad companies, increased enormously the amount of time that a locomotive can be kept outside of the repair shop. Yet, this same locomotive boiler if removed from the rails, put on a brick foundation, automatic stoker fed and run at sixteen pounds pressure, will insure the owner being put in jail.

If an arc welded boiler, tomorrow morning, should explode and kill a man, it is safe to say that it would be broadcast from one end of the country to the other by a number of journals. The fact, however, that on an average there is one killed every day by the explosion of a riveted boiler does not even gain passing notice.

I am not citing this as an argument at all in favor of welding—I am merely citing the fact.

Practically without exception every automobile depends for its success on electric arc welding, and if the electric weld fails in service, most automobiles would be wrecked, with enormous loss of life. In fact, it is safe to say that practically no automobile (with the exception of the Ford), is in operation today which does not have such parts of it arc welded so that if the weld failed a serious accident would result.

Many automobiles not only have the rear axle housing completely made by arc welding, but in almost all cases have the drive shaft and brake hangers completely arc welded, thus the ability to start, run and stop, and to stay on their wheels all depend on arc welding.

I think it is safe to say that arc welding in the automobile industry (if it were found defective) would be ten times more destructive of life than if all the boilers in the country should explode at once.

I am citing these cases in the hope that we engineers may take a logical viewpoint on this great question. It is certainly true that if arc welding is dangerous it ought to be eliminated in any place where its failure will endanger life, but it certainly is a very poor recommendation for engineers and the engineering profession to allow conditions to exist such as are existing at the present time in which arc welding is eliminated from a boiler shell but used in the superheater in the same boiler, where arc welding is eliminated from air receivers but is used completely in a cracking still, where arc welding is satisfactory on a locomotive boiler, but unsatisfactory and eliminated by law in a stationary boiler, where arc welding is eliminated by law from a tank car but specified in the tank into which the tank car is emptied.

The engineering profession is founded fundamentally on logic—if an engineer is not logical, to whom then shall we turn?

Structural Steel Welding Investigation* Westinghouse Elec. & Mfg. Company

A. M. CANDY†

The investigation by the Westinghouse Electric & Manufacturing Co. of the Application of Arc Welding to the Fabrication of Structural Steel was started about the middle of 1925. The object of this investigation was primarily to determine the reliability of this process in order that it might be more extensively applied in the company's various manufacturing processes, it being the opinion

*To be presented at the Annual Meeting, A. W. S., April, 1927.
†General Engineer, Westinghouse Electric & Mfg. Company.

of those interested in the subject that its use would bring about many savings over the present method of joining structural steel members in the manufacturing sections.

The first tests consisted of simple bracket and beam connections which proved very satisfactory. Later, welded structures were subjected to vibration and shock tests. The results of these tests also proved quite satisfactory, and a definite program was arranged to carry on a series of tests that would prove the suitability of the process for major building construction. On July 28 and 29, 1925, these tests were conducted at the Carnegie Institute of Technology, in cooperation with the American Bridge Co. A report of these tests is given in the Westinghouse Special Publication 1767.

During June and July, 1926, a laboratory building and an addition to an existing building were erected at East Pittsburgh. The first involved 115,800 lb. and the second 70,000 lb. of structural steel. The work on these buildings was completed at an average saving of 11.5 per cent of the contract price for rivet erection.

During the last quarter of 1926 the American Bridge Co. fabricated and erected through the Westinghouse Co. a five-story mill type building at the Transformer Works at Sharon, Pa. Seven hundred and ninety tons of structural steel were used in this building, which was a saving of 65 tons as compared to the amount of steel required for a riveted building. This building is probably the largest structural steel building specially designed for and erected by the arc welding process. The final cost figures on this building are not yet available.

The Research Department of the Westinghouse Co. has carried on a series of tests to show the change in physical strength of weld metal at high temperatures. The result of this test shows that while the tensile strength is reduced 25 per cent, the elongation is increased over 50 per cent, and the reduction in area over 50 per cent when the weld metal is heated to a temperature of over 850 deg. Fahr.

The present problem which now confronts this company is to use the information they have obtained and introduce this new method of fabrication to the various departments of their work, which it is expected will result in more economical fabrication of structural steel.

Research Activities of the Metal and Thermit Corp.*

J. H. DEPPELER†

The reduction of metallic ores and oxides is a science to which man has paid probably more attention than to any other and out of it has grown the enormous steel industry of the world. Practically all of this study, however, has been given to the reduction of these metallic ores and oxides by means of carbon because this reducing agent is the cheapest. Aluminum as a reducing agent has been known for many years, but originally the cost of the aluminum was so great that it was impractical to use it for this purpose, but, as years went on and the cost of aluminum decreased, serious thought was given to the practical use of it as a reducing agent by many inventors. The usual method was to mix the metallic ore or oxide with finely divided aluminum, place it in a crucible and heat externally until the whole mass had reached a temperature at which the reaction would start; and such methods were used for years by such inventors as Moissan, Greene and Wahl. The difficulty with this method of reduction was not only the cost of the reducing agent but the fact that when the mass had reached the temperature at which the aluminum would combine with the oxygen of the ore, forming the aluminum oxide and liberating the metal, the reaction would proceed so rapidly and with such an ebullition of heat that the result was practically an explosion resulting in an inefficient production of metal and the loss of much of the contents of the crucible. Furthermore, the extremely high temperature of the reaction—something over 5000 deg. Fahr.—would very rapidly disintegrate the crucibles and thus add considerably to the cost of production. It remained for Dr. H. Goldschmidt, a German inventor, to discover that a cold mixture of such an oxide with finely divided aluminum could be ignited in one spot internally, and that when the reaction was thus started, the heat of the reaction would progress through the mass until the entire mass had been reacted. This idea made a success of this reduction process, where it had been a failure up to that time. The internal ignition eliminated the entire cost of the external heating of the crucible and mixture; it caused the reaction to go on progressively, within perfect control of the operator, and consequently without any explosive violence. It made possible the use of crucibles made of refractories which were not good conductors of heat and which refractories were, therefore, much better able to withstand the extremely high temperatures. This invention, therefore, resulted in the beginning of what has been since recognized as the

*To be presented at annual meeting, A. W. S., April, 1927.
†Chief engineer, Thermit Dept., Metal & Thermit Corporation.

science of Alumino-Thermics, and this beginning was practically only about twenty-five years ago.

The research activities of the Metal & Thermit Corp. are carried on at its Jersey City plant. The work divides itself into three general classes:

First: The welding research which has to do with the development of Iron Thermits that will produce steels of the proper physical characteristics, the development of all the other materials necessary in the thermit welding process, and the development of a thermit welding technique to produce the best results.

Second: Research on the production of other metallic ores and oxides than iron oxide resulting in the efficient production of what are commonly known as the refractory metals, such as, Manganese, Chromium, Titanium, Vanadium, Tungsten, Molybdenum and the various alloys with or without iron.

Third: Research on other uses of metallic ores and oxides.

In this paper we will discuss only the first of these not because the others are not of great importance but because the first is more interesting to the American Welding Society.

In the Jersey City plant the research men include all of the staff at the plant, and the work is carried on through a few employed for research alone and through the larger number of expert thermit welders that the corporation has developed for demonstration and instruction purposes. The men have the facilities of a large, well equipped chemical laboratory supplemented with a research laboratory with its grinding mills, gas fired and electrically heated muffle furnaces, crucible furnaces, Arsem furnaces and the heavier chemical apparatus; but the development of the thermits themselves and the technique of thermit welding must be done on a larger scale and this work is carried on in the specially equipped foundry. Next to the foundry building is the machine shop building, an important part of the work of which is the machining and sectioning of the welds, and the rough preparation of specimens for the metallographic examination. A separate room near the laboratories is equipped with the metallographic apparatus, as well as all facilities for the polishing and etching of specimens, their subsequent examination and micro-photography. Another important part of the research is the study of results through the medium of carefully made photographs and the study of entire welding operations through the motion picture camera; this latter is found of greatest importance because many of the details of the welding operation occupy such a short space of time—often only a fraction of a second—and the heat and light is frequently so great that proper observation is difficult, but with a camera where twenty to thirty exposures are made per second, many important details are made visible which might otherwise escape notice.

Because of the fact that Stevens Institute of Technology is only

a few miles from the Jersey City plant it has been found much more convenient to use the excellent facilities of the testing laboratories at Stevens than to equip its own research station with these machines.

The research staff is fortunate in having at its disposal materials from not only all parts of the United States but from allied companies in other parts of the world as well. Much study is given to the various oxides available for the production of thermit, their chemical analyses, physical size and the results of the proper treatment and blending of these in the processes with the result that the thermit of today is not made of one untreated oxide mixed with aluminum and certain additions as was the case twenty years ago, but is composed of seven carefully selected oxides mixed and blended in very definite proportions. The result, as far as the customer is concerned, is that the thermit steels which twenty years ago were un-uniform, whose fractures would show large crystal faces and whose maximum tensile strengths were only about 50,000 lb. per square inch with unimportant ductility, are now almost perfectly uniform with fine grained structure, with tensile strengths of 70,000 lb. per square inch or over, and ductility which will allow any amount of forging, bending and deformation—in fact, steels which in many respects are superior to those which go into the manufacture of the high grade machine tools of today.

It would be impossible to outline in this paper in any sort of detail the great amount of important work done in these research laboratories, much of which has been accomplished in the last ten or fifteen years, and a brief outline of the results obtained does not give one a real impression of the enormous amount of work done and the great mass of records collected, but anyone familiar with research work at all must realize the hundreds of blind alleys and the alternate enthusiasm and discouragement occasioned by the following of theories which subsequent work proves fallacious. We will, however, mention a few of the important results obtained:

1: The production of a thermit which, under all circumstances, reacts uniformly and produces sound, fine grained steel of high ductility and tensile strength over 70,000 lb. per square inch, which can be forged, worked and bent double on itself without harm.

2: The production of crucible lining materials and molding materials to withstand the high temperatures of 5000 deg. Fahr. or over without the introduction of any harmful elements into the steel and without the introduction of gases, which was one of the great faults of the former materials used.

3: The development of a welding technique in simplified form which not only has made possible the production of sound, strong welds every time, even by relatively inexperienced operators as long as they are capable of following instructions, but which has, furthermore, in the last five years cut the cost of the thermit weld-

ing operation in half, not only in its rail welding application but also in its application in the railroad shop, steel mill, foundry and machine shop.

To these men of the research staff belongs the credit for having brought the thermit welding process from one having an occasional application and relatively unknown to the average engineer and general public to a process taking its position as one of the four important welding processes—Oxy-acetylene, Electric Arc, Resistance and Thermit.

Outline of Research Activities, Una Laboratory*

R. B. FEHR†

I. WELDING MACHINES AND EQUIPMENT

A. Single Operator Industrial Welders:

1. 300 ampere capacity on alternating current.
2. 400 ampere capacity on alternating current.

NOTE: The design of these machines is such as to give a drooping voltage characteristic with high power factor and an efficiency rising with increase of arc current.

B. Two Operator Industrial Welders:

1. 400 ampere unit built for two-operator use.

NOTE: Characteristics and regulation are such that one operator causes no interference with the other operator.

C. Railway Type D-4 Welder:

1. 400 ampere capacity for single, or two-operator use for 250 or 550 volt D.C. lines.

II. INDUSTRIAL WELDING

A. Welding Rods:

1. Uncoated Rods.
   a. Effect of chemical constitution.
   b. Effect of occluded gases.
   c. Influence of surface condition.
2. Coated Rods.
   a. Influence of coating as regards flowing properties, penetration, magnetic disturbance, speed of deposition, ductility, tensile strength, resistance to repeated impact.
   b. Possibilities of obtaining alloy deposits from coated electrodes.

---

*To be presented at Annual Meeting, A. W. S., April, 1927.
†Development Engineer, Una Welding & Bonding Company.

c. Strength and ductility of coatings, and effect of various binders.
d. Processes for manufacturing coated rods.

B. Adaptability of Various Rods to Different Welding Problems.
C. Application of Metal Arc and Carbon Arc Processes to the Welding of Structural Steel.
D. Grain-refining During Welding.

III. BONDS AND BONDING PROCESSES

A. A Study of the Fatigue Properties of Rail Bonds:
1. Free cable length.
2. Cable lay and twist developed in manufacture.
3. Form of cable loop.
4. Comparative annealing, when applied by gas and arc welding processes.
5. Shape and size of strand or lamination.

B. Applications of Rail Bonds to Various Parts of Rail:
1. Ball.
2. Lip of girder rail.
3. Flange and web.
4. Under-rail.

C. Electrical Resistance of Copper to Steel Welded Bond:
1. Contact resistance.
2. Bond head resistance.
3. Comparison of gas and arc welded bonds.

D. Effect on Rail:
1. Bend tests, drop tests, microscopic investigations.
2. Comparison of steel and copper welded bonds and gas and arc welding processes.

E. A Study of Mold Materials and Methods of Combining Bonds and Molds for Application by the Copper Arc Process.
F. A Study of the Junction of Copper-to-Steel Welds.
G. Applying Rail Bonds by the Gas Welding Process.

IV. RAIL JOINT WELDING

A. Effect of various magnitudes of energy per blow in making repeated impact tests of seam welded joints.
B. Determination of "endurance curve" of a typical seam welded rail joint.
C. Determination of probable life of welded rail joint—based on telemeter and strain gage tests of joints in service, supplemented by "endurance curves" of joints tested in laboratory.
D. Investigation of the effect of various locations of seam welds, effect of seam welds on the rail, carbon arc vs. metal arc, etc.
E. Determination of the minimum length of plate, and minimum amount of weld metal to give adequate strength and durability.

Developments and Research in Welding*

D. H. DEYOE†

NEW MAGNETIC CLUTCH TYPE AUTOMATIC WELDER AND CONTROL

This new welder differs from its predecessor in that the motor revolves at a constant speed in one direction, merely turning the horizontal shaft which carries the two beveled magnets shaped like two truncated cones. This constant speed can be adjusted to various values, but once set for a particular job it remains constant.

When the main line contactor of the welding circuit is closed, the generator voltage is applied to one of the two magnet coils of the clutch by the TR voltage relay which is actuated by the arc voltage. In starting up the "feed-in" magnet coil is energized by the relay. The motor-driven shaft carrying the driven magnets is moved or shifted horizontally by the magnetic pull, bringing the feed-in magnet into contact with the driven magnet and forming what might be called a magnetic gear. This feeds the electrode forward until it touches the work.

Incidentally, with the magnets in contact on the feed-in side, the air gap between the "draw-back" magnet and the driven magnet is about ten thousandths of an inch. The bevel of the magnets is 26 deg., so the total shift of the horizontal shaft is about twenty-two thousandths.

When the electrode touches the work the voltage across the arc drops to zero, the TR relay energizes the draw-back coil, the horizontal shaft is pulled over bringing the draw-back magnet into contact with the driven magnet and the arc is formed by the drawing back of the electrode.

This reversal of the feed and the drawing out of the arc takes place almost instantaneously. One of the marked advantages of this new magnetic clutch type is its quick action due to the practical elimination of inertia of moving parts. In the superseded type the feed motor armature had to be stopped and reversed.

After the arc is formed it is drawn out to its proper current value as determined by the arc voltage, which is set by means of the adjusting rheostat in series with the TR relay coil.

Thereafter, the arc voltage, and its corresponding welding current is held fixed by the extremely rapid vibration of the TR relay actuating the feed-in magnet coil. So rapid is this vibration that, although the feeding-in is really a series of infinitesimal advances, the welding wire is moved forward with a very smooth flow.

TRAVEL CARRIAGE FOR AUTOMATIC WELDERS

To carry the Automatic Welder along a seam to be welded, a carriage was developed. The carriage is propelled by a variable speed

*To be presented before the Annual Meeting of the A. W. S., April, 1927.
† Industrial Engineering Dept., General Electric Co.

direct-current motor and is provided with one gear shift, the combination giving any speed from 3 to 27 in. per minute.

The carriage is self-contained, having mounted upon it the Automatic Welder, Wire Reel Meter Panel and Push Button Controls. The motor control is usually interlocked with the arc, so that the travel starts immediately upon the starting of the arc and stops when the arc is extinguished.

Multiple Arc Automatic Welder

Research has proved conclusively that a faster, stronger and more homogeneous weld can be made on one ½-in. plate or thicker, by depositing the welded metal in two or more layers, using around 350 amperes in each arc, rather than trying to deposit the metal in one layer, using an excessively high amperage.

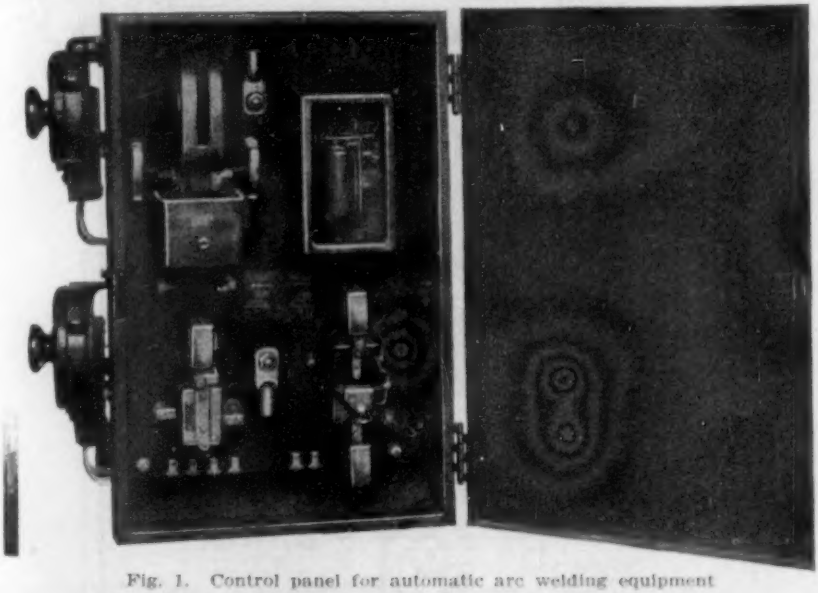


Fig. 1. Control panel for automatic arc welding equipment

With the comparatively low current in each arc, the danger of burning the deposited metal is remote. The metal in the first and each successive layer deposited is heat treated or refined by the heat from the molten metal of the second and each successive layer.

The Multiple Arc Automatic Welder was developed to accomplish the above.

Straight Seam Welders for Range Boilers, Small and Large Tanks and Pipe

In order to properly and conveniently weld the longitudinal seams of tank and pipe, some arrangement is necessary whereby the edges of the seam may be held firmly in position. Some member must be held tightly against the underside of the seam to

"back up" the weld and prevent molten metal from running through and projecting in irregular beads along the side of the seam. This backing is also necessary to prevent the arc from "burning" through the metal and making a hole in the seam. In order to permit the maximum production, this arrangement must allow of rapid insertion and removal of the tank shells and of quick manipulation of the clamp.

There have been developed a line of machines suitable for welding the side seams of cylindrical tanks and pipe ranging all the way

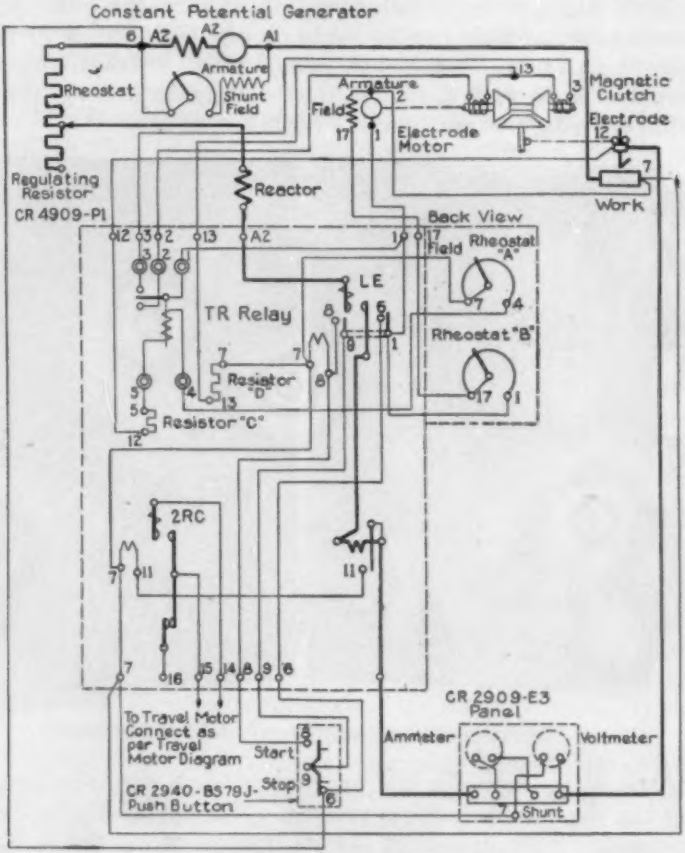


Fig. 2. Wiring diagram of control panel

from small ice-cream cans to large pipe 30 ft. long. The machines consist of three horizontal beams, two above and one below, and so arranged that when the lower beam is forced up against the two upper beams the seam to be welded is held firmly in position. The two upper beams are parallel, spaced about 6 in. apart, and to their long edges two copper jaws are attached. These jaws have a space the proper width for welding between their edges, and the two upper beams are attached rigidly to the frame work of the

machine. The lower beam or "backing-up" member consists of a steel bar with a copper strip inserted on its upper side. This steel bar is supported by a series of plungers which rest on a diaphragm carried on a heavy cantilever beam.

Compressed air is admitted to the diaphragm by a three-way valve and forces the plungers upward and sets the backing-up member tightly against the seam, thus clamping the shell against the upper jaws. The space between the upper and lower beams is adjustable to accommodate different thicknesses of tank shells.

Control of Magnetic Fields in the Arc When Welding

When welding with the electric arc, magnetic fields have a very marked effect both on the behavior of the arc and upon the resultant weld. These fields are always present owing to the current flowing through the work, the arc and the electrode. There are also

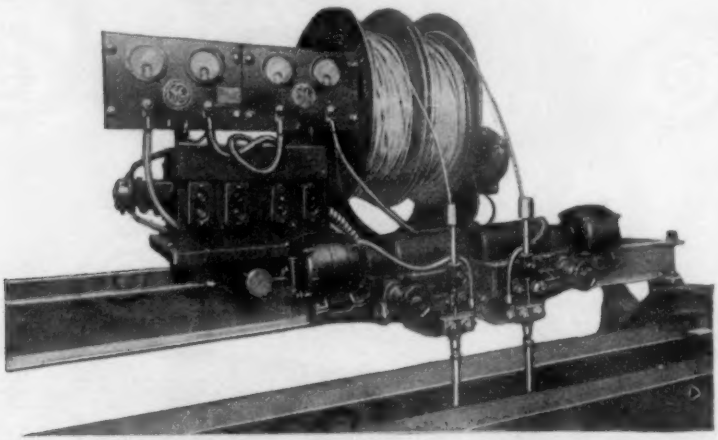


Fig. 3. Travel carriage with two heads for automatic welding machines

other fields due to the work and clamping fixtures becoming magnetized.

When the resultant field is of the proper magnitude and direction the arc will be quiet, will be blown slightly in the direction of travel, and the resultant weld will be good.

However, if the magnetic field is not of the proper magnitude and direction, the results are quite often very discouraging. If the field is too strong, the effect may be great enough to actually blow the arc out, or if in the wrong direction, may cause the arc to blow backward so that the electrode comes too close to the cold metal and short circuits.

Through research it was determined that by passing a part of the welding current through an insulated conductor directly below the weld a magnetic field was established through the backing bar, the work and through and around the arc. This field can be so con-

trolled that the arc will always blow forward and melt the work slightly in advance of the electrode.

Pneumatic Backing Bar

An automatic arc welding machine is essentially a production tool and as such must function at maximum speed and deliver a product of uniform quality.

If the seam to be welded is not tightly and uniformly backed up

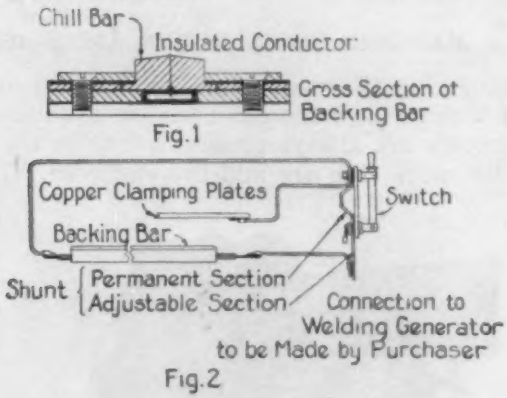


Fig. 4. Magnetic control circuit apparatus for longitudinal seam welders

Fig. 5. Pneumatic flexible backing bar

on the lower side, the arc becomes a cutting tool instead of a welder and leaves holes wherever the air gaps occur.

To give the desired uniform backing the pneumatic clamping mechanism was developed. This consists of a diaphragm made of fire hose, inclosed in the lower box girder beam, on top of which rest a series of plungers, which in turn support a flexible backing-up bar.

Circular Seam Welders

As with the straight seam welders, it is necessary, in order to properly and conveniently weld the circumferential seam of tanks,

range boilers and pipe to have some arrangement whereby the tank may be rotated at the proper speed for welding. The speed of rotation must be easily adjustable so that it can be changed for various sizes of tanks and thicknesses of shell.

To accomplish this, there has been developed and placed on the market a line of rolling devices covering various applications.

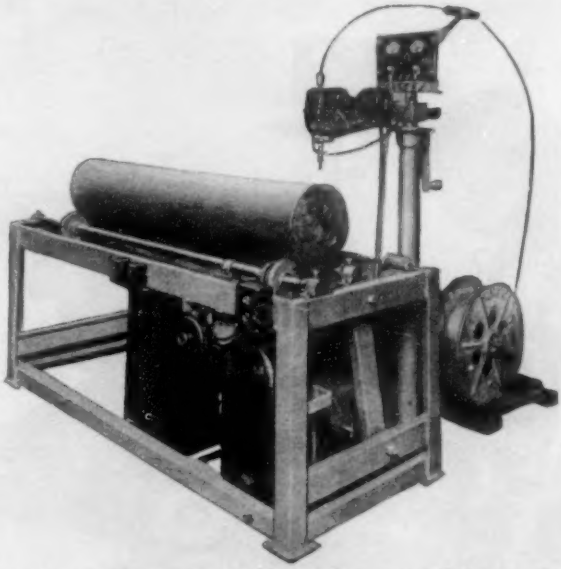


Fig. 6. Circular seam welder for range boilers and small tanks

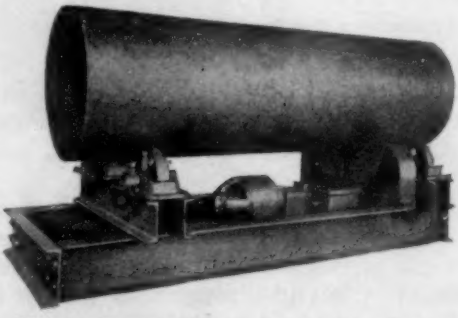


Fig. 7. Tank rolling mechanism for tanks

Atomic Hydrogen Welding and Shrouded Arc Welding

During the last two years two distinct investigations and developments have been carried on, one in the Research Laboratory of Dr. Elihu Thomson under his direction at Lynn, Mass., and the other in the General Electric Research Laboratory at Schenectady, under the direction of Dr. Irving Langmuir. These two methods are entirely different—the one by Professor Thomson being called

"Arc welding in a hydrogen atmosphere," the other by Dr. Langmuir being called "Atomic hydrogen arc welding." Arc welding in a hydrogen atmosphere involves the same principles as straight metallic arc welding, except that the metallic electrode and arc are surrounded by an envelope of burning hydrogen. In the atomic hydrogen arc welding process an arc is drawn between two tung-

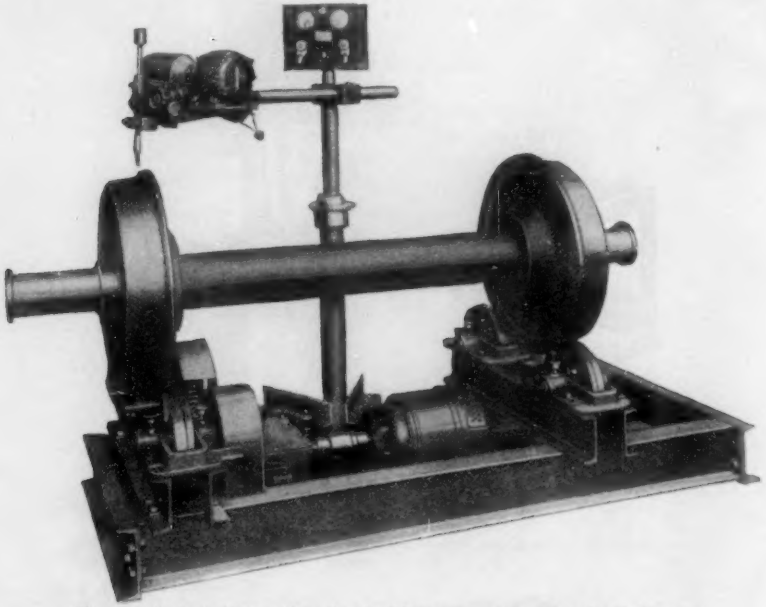


Fig. 8. Automatic welder for building up worn car wheel flanges

sten points and then a jet of hydrogen is shot through this arc. In passing through the arc, the molecular hydrogen is broken up into atomic hydrogen, and upon re-combining, generates intense heat.

As both of these processes block off the air from the arc, entirely avoiding any oxidization of the metal deposited and eliminating all oxides and nitrides from the deposited metal, the resulting weld is extremely ductile and strong. As we see these two processes, the metallic arc welding in hydrogen where metal is added gives promise of wide usefulness in the welding of pressure tanks, high pressure pipe lines, and any welding where strength and ductility are desired. The atomic hydrogen arc welding, where no metal is added, will do the same in the manufacture of thin metal parts such as oil drums, paint cans, etc. Neither method will supersede the present method of automatic metallic arc welding, but will greatly broaden its application. These are being developed for use as automatic welding machines. The apparatus for both of these methods is still in the developmental stage.

Atomic Hydrogen Welding

For detailed description see Messrs. R. A. Weinman and Irving Langmuir's paper in the March, 1926, issue of the AMERICAN WELDING SOCIETY JOURNAL, pages 32 to 46.

Shrouded Arc Welding

For detailed description see Mr. P. Alexander's paper in the March, 1926, issue of the AMERICAN WELDING SOCIETY JOURNAL, pages 46 to 55.

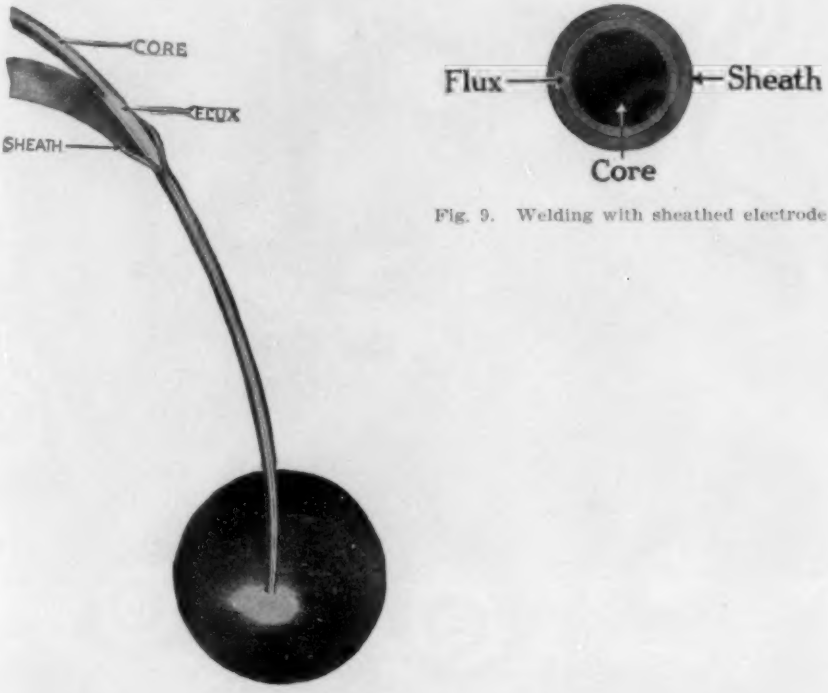


Fig. 9. Welding with sheathed electrode

ELECTRODES

A great amount of research work has been done to determine the best grade of steel to use and the proper ingredients of the flux for different grades of electrodes.

One of the main reasons for the development of the metallic sheath-covered fluxed electrode was the demand for a fluxed electrode for use in automatic welders. An electrode fluxed on the outside cannot be fed through the rolls of the automatic welder when the flux retards the passage of current into the electrode and when the flux will flake off in passing through the feed rolls.

The speed of welding with this electrode is increased approximately 20 per cent over that of bare electrodes.

Sheathed wire has also been developed for use on cast iron and for overhead welding.

New Type of Bare Welding Electrode

A new bare welding electrode which combines the characteristics of a fluxed electrode and the quality of bead finish and the clean-

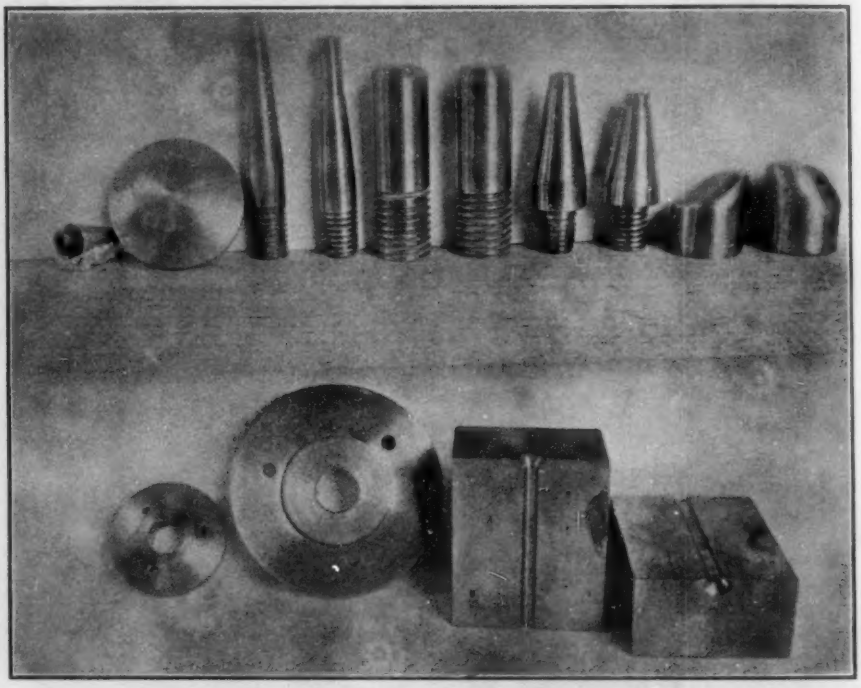


Fig. 10. Copper tungsten resistance welding electrode

ness in handling of a bare welding electrode has been developed. Recommended for the general welding of steel, the electrode has a uniform flowing quality and the minimum amount of sputtering or spattering are some of the features of the new electrode. The elimination of the erratic arc condition leads to a deposit of more material with the same consumption of electrode per kilowatt-hour. The electrode penetrates quickly and produces high tensile strength and unusual ductility and elongation.

Metallurgical Research

The General Electric Company started on Jan. 1, 1927, a Research Department to study welding from a metallurgical standpoint.

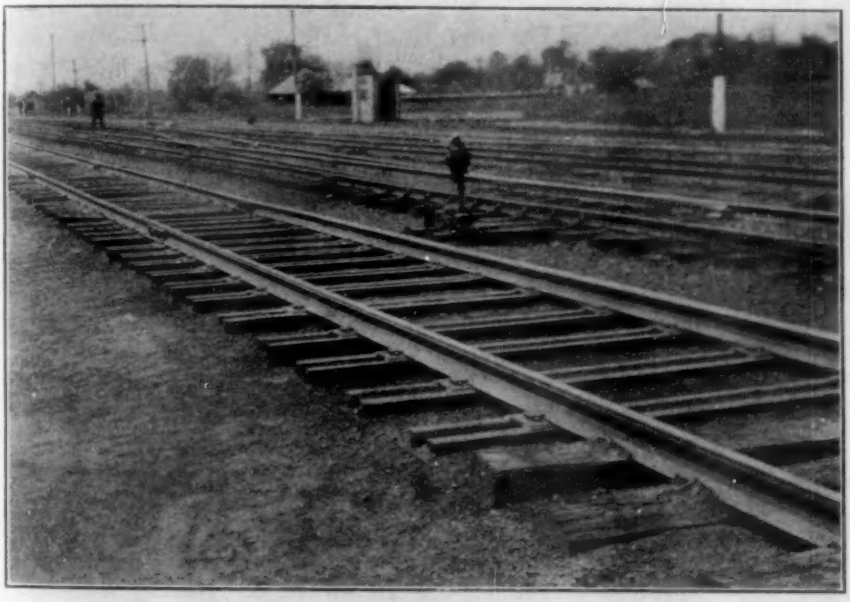
A study is now being made on the quality of the plate to be welded. The program includes a study of the welding current on the quality of the weld, particularly as to ductility, also the effect

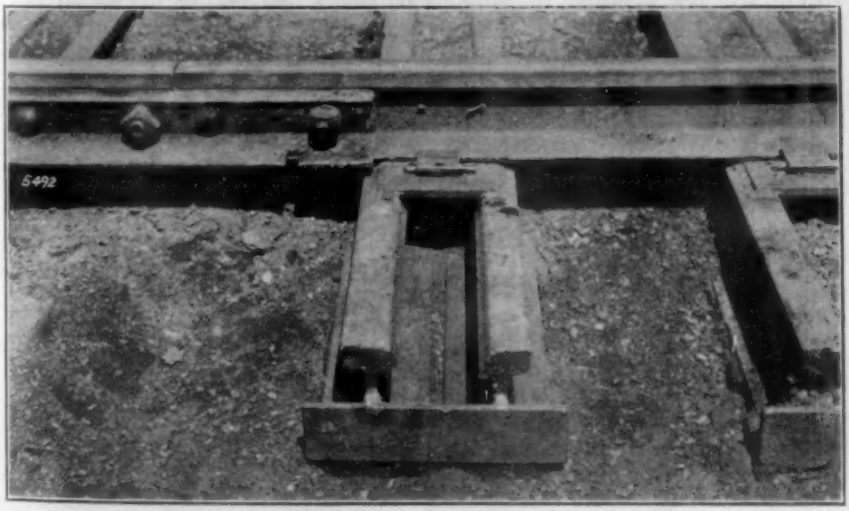
of the structure of the electrode on the arcing characteristics of the electrodes.

There is no report available at the present time, but one should be completed before the fall meeting of the American Welding Society to be held in Detroit.

Copper-Tungsten Electrode for Spot Welders

Copper-tungsten electrode, a development which is expected to





Figs. 11 and 12. All steel arc welded railroad tie

prove of great value in the fabrication of metals, is now available for use in manufacturing. Copper-tungsten, as its name indicates, is a mixture of two metals, one a good electrical conductor and the other very hard. The compressive strength of the copper-tungsten is 208,000 pounds per square inch as against 58,000 pounds per square inch for hard copper.

One of the limiting features in many resistance or spot welding operations has always been the copper electrode used, the pure copper not being hard enough when used under the high pressures at high currents common to this type of welding. Usually, after a few welds are made, the surface of the copper electrode in contact with the weld becomes hot enough to anneal the copper, thus making it very soft. As a result, the copper tip rolls and mushrooms over the edges, giving a large spot weld which changes the current density and consequently the quality of the weld.

The material has been given the trade name "Elkonite," and is sold by the Elkon Works, Inc.

All Steel Arc Welded Railroad Tie

Metal railroad ties constructed by electric arc welding from worn rails are not only ten times as strong as ordinary wooden type of tie, but can be made at a very low cost. This was developed by Mr. William Dalton of the Manufacturing General Department of the General Electric Company. He, in collaboration with Mr. H. S. Clarke, engineer of Maintenance of Way, Delaware & Hudson Railroad, recently completed a test extending over a period of a year.

A number of sample ties were installed by the D. & H. about a year ago in its Glenville Yards. The test has been so successful that Vice-President Loree of the Delaware & Hudson Railroad Company has decided to undertake the substitution of metal for wooden ties in yards and sidings, and arrangements are now being made by that company to install equipment in its shops for the construction of the ties.

An automatic welding and clamping machine has been developed for the welding and handling of the parts making up the completed tie, and it is expected that this machine will turn out 15,000 completed ties per year.

Welding Research Activities of the Newport News Shipbuilding & Dry Dock Company During 1926*

JAMES W. OWENS†

The resistance, gas, arc and thermit welding processes for the uniting of materials being comparatively new in comparison with the forge welding and riveting processes, there is much to be desired in the way of technical information and a dissemination of available knowledge before these processes can fully come into their own in industry.

As the Newport News Shipbuilding & Dry Dock Company is now using extensively all of these welding processes in the manufacture of its products and proposes to use them even more so in the future, that is, insofar as a better or cheaper product is obtained by their use, a research and test program became a necessary part of this development.

The principal reasons for conducting any specific research or test in this program are as follows:

(a) To obtain fundamental information on welding.
(b) To test new or untried welding processes, equipment and supplies.
(c) To try out a welding process or processes on some specific job to determine suitability, relative costs, etc.
(d) To convince a customer or a Classification Body.
(e) To educate the company's executives and employees.
(f) To test welders on completion of training to determine their ability to make sound welds.
(g) To certify welders in the company's employ.

As a paper outlining in detail all of our welding researches and tests conducted during 1926 would be too extensive, it will only be possible for me to list some of them, summarize the reasons for conducting same, briefly state the method of procedure and give the conclusions (in some cases tentative) deduced.

RESISTANCE WELDING

TEST NO. I

To determine the technic of spot welding galvanized iron, No. 24 to No. 11 U. S. S. Gage.

Reason for Test

The substitution of spot welding for riveting on light galvanized iron vent ducts of ships with a view of lowering the cost of manufacture and the training of the shop organization in the technic required.

*To be presented at the Annual Meeting, A. W. S., April, 1927.

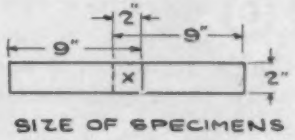
†Director of Welding, Newport News Shipbuilding & Dry Dock Company, Newport News, Va.

Test Procedure

Information on the latest industrial practice was first obtained from various resistance welding companies. Several specimens were then welded and surfaces pried apart with a chisel.

Conclusions

Information secured and tests made show that the spot welding of No. 24 to No. 11 gage galvanized sheet iron and steel is not only entirely practicable but very satisfactory. The requirements



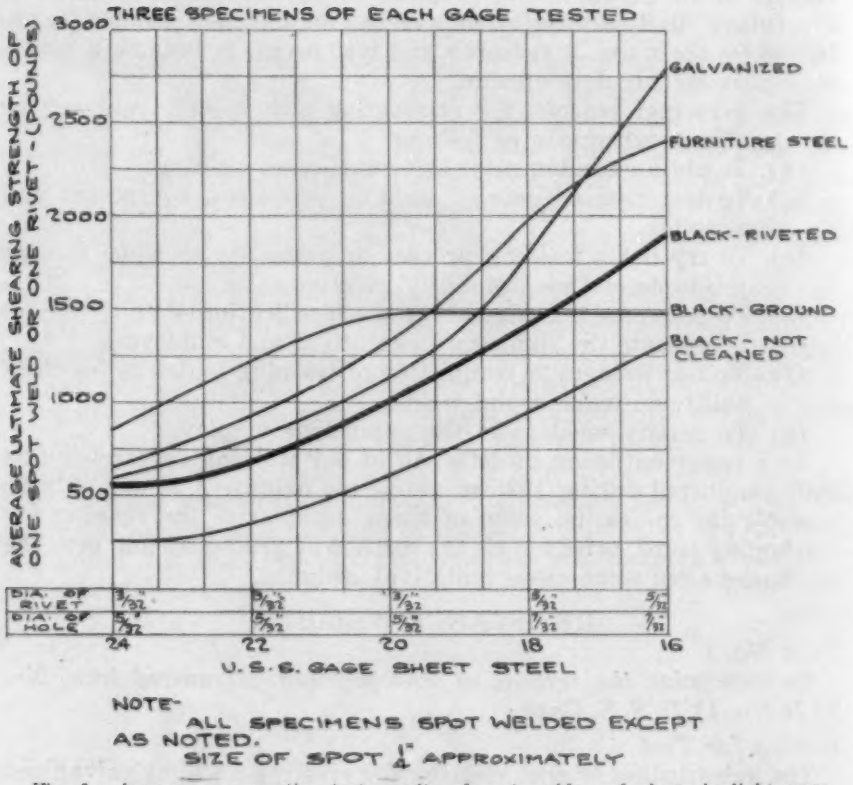


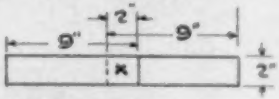
Fig. 1. Average comparative test results of spot welds and rivets in light gage material

for successful welds being: rounded die points, twice the current and half the pressure required for black metal. The zinc adhering to the electrode points should not be removed and the points should

be kept in shape by frequent filing. Figs. 1 and 2 show comparative test results obtained a few years ago by the writer at the Norfolk Navy Yard.

TEST No. II

To determine the best technic for the flash welding of tungsten steel tips to medium carbon steel shanks in the manufacture of



SIZE OF SPECIMENS

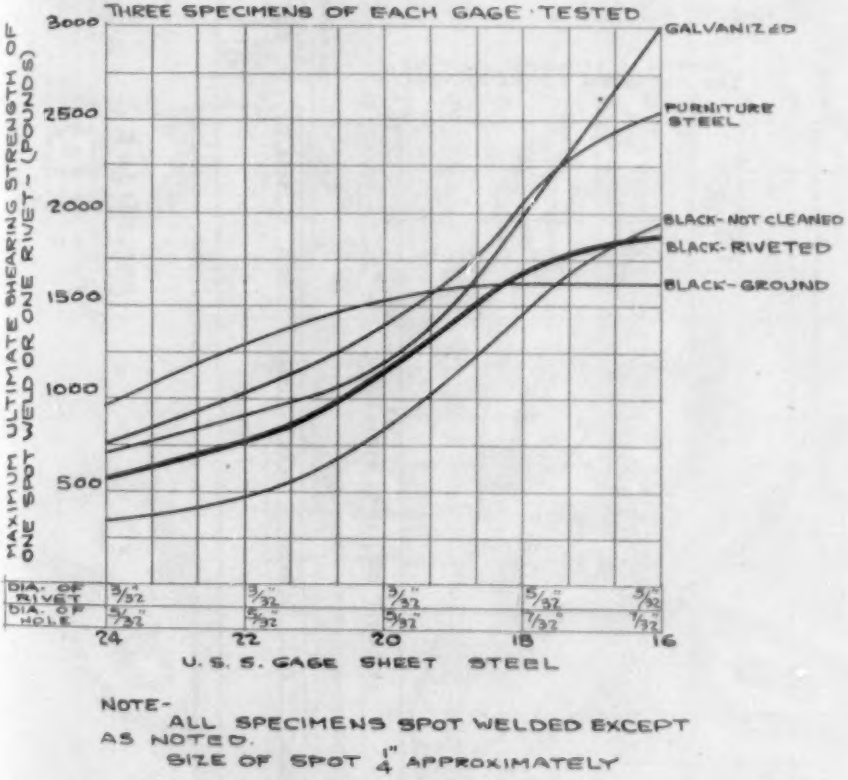


Fig. 2. Maximum comparative test results of spot welds and rivets in light gage material

lathe and planer tools and the serviceability of such tools as indicated by bending and service tests.

Reason for Test

To reduce the cost of high speed tools which were previously made by our company from bar stock; to convince the company's

executives of the practicability of this method of manufacturing lathe and planer tools with our present equipment and for the salvaging of broken drills and tools. Finally to train our shop organization in the technic required.

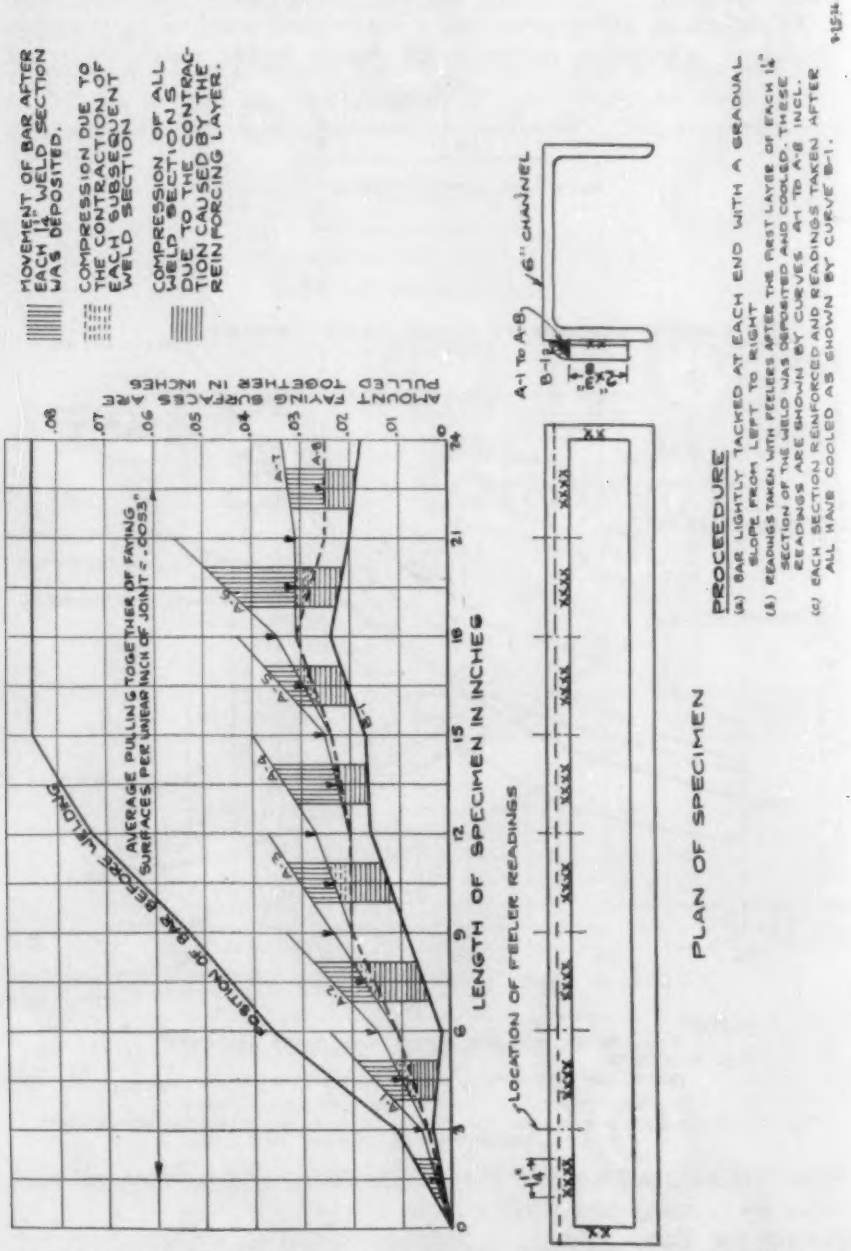

MOVEMENT OF BAR AFTER EACH ¼" WELD SECTION WAS DEPOSITED.
COMPRESSION DUE TO THE CONTRACTION OF EACH SUBSEQUENT WELD SECTION
COMPRESSION OF ALL WELD SECTIONS DUE TO THE CONTRACTION CAUSED BY THE REINFORCING LAYER.
AMOUNT FAYING SURFACES ARE PULLED TOGETHER IN INCHES
AVERAGE PULLING TOGETHER OF FAYING SURFACES PER LINEAR INCH OF JOINT = .0033"
POSITION OF BAR BEFORE WELDING
LENGTH OF SPECIMEN IN INCHES
LOCATION OF FEELER READINGS
A-1 TO A-8
6" CHANNEL
PLAN OF SPECIMEN
PROCEEDURE
(a) BAR LIGHTLY TACKED AT EACH END WITH A GRADUAL SLOPE FROM LEFT TO RIGHT
(b) READINGS TAKEN WITH FEELERS AFTER THE FIRST LAYER OF EACH ¼" SECTION OF THE WELD WAS DEPOSITED AND COOLED. THESE READINGS ARE SHOWN BY CURVES A-1 TO A-8 INCL.
(c) EACH SECTION REINFORCED AND READINGS TAKEN AFTER ALL HAVE COOLED AS SHOWN BY CURVE B-1.

Fig. 3. Diagram showing amount faying surfaces of metal arc welded lap joints are pulled together by the use of intermittent welds—two layer reinforced

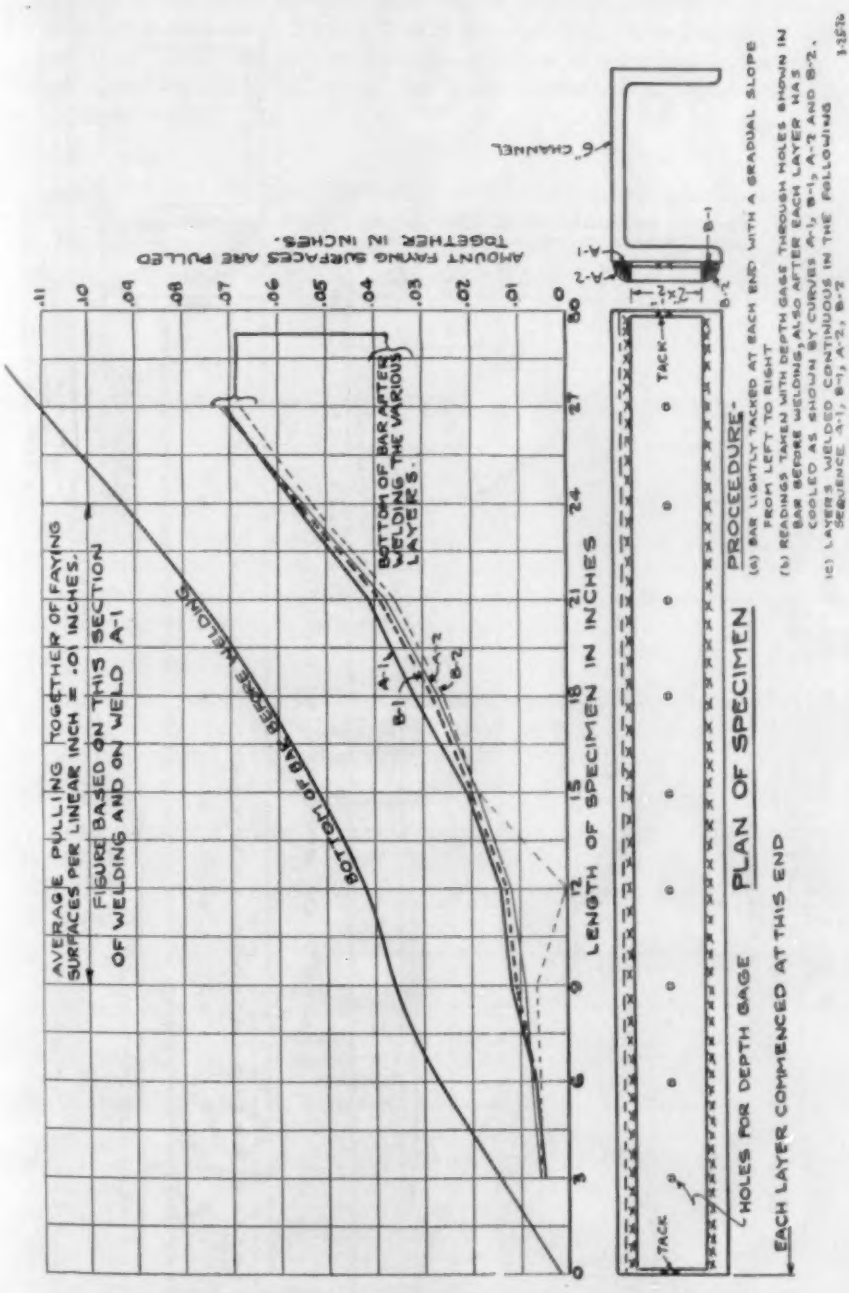


Fig. 4. Diagram showing amount faying surfaces of metal arc welded lap joints are pulled together by the use of continuous welds—two layer reinforced

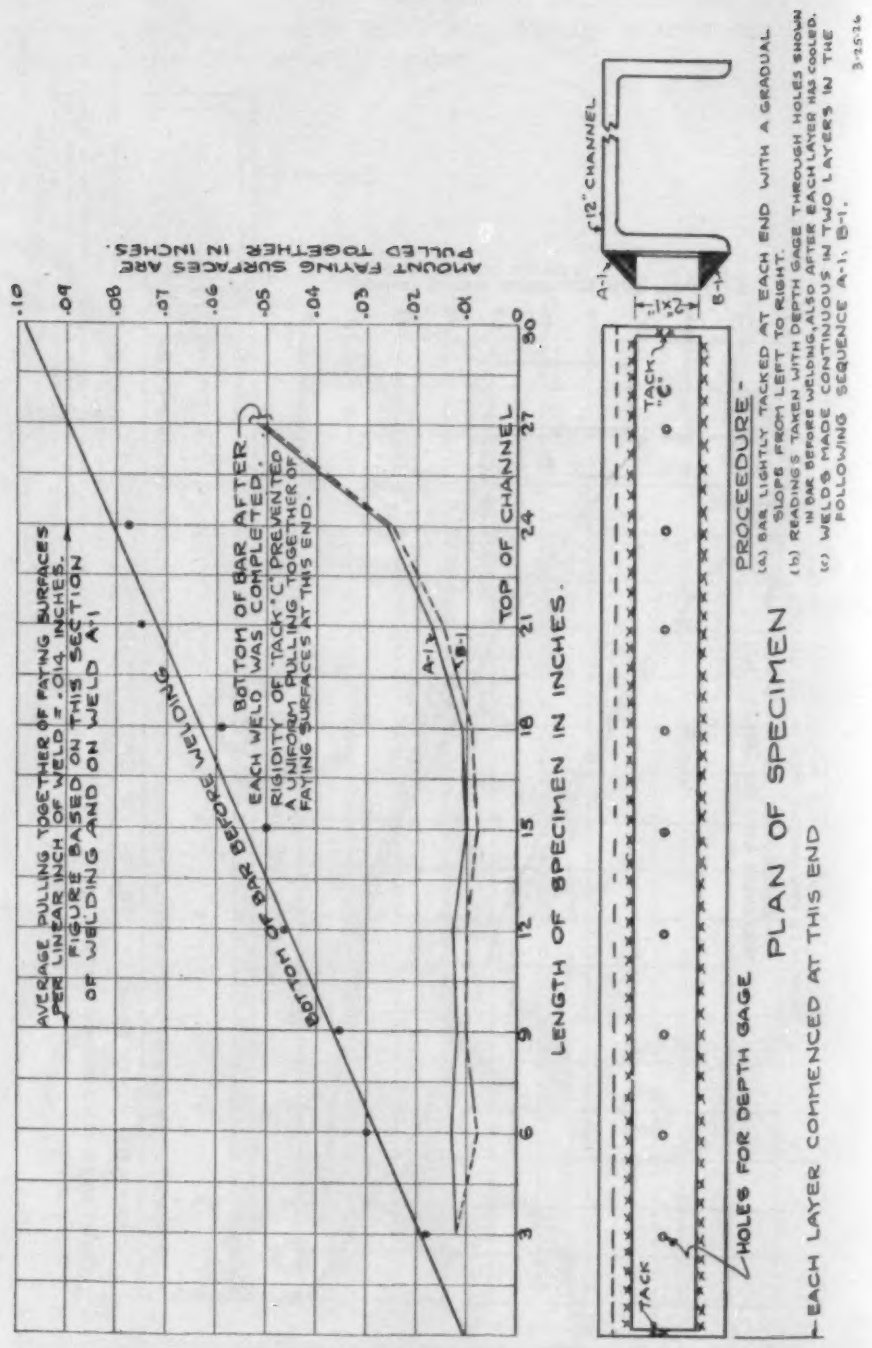

AVERAGE PULLING TOGETHER OF FAYING SURFACES PER LINEAR INCH OF WELD = .014 INCHES. FIGURE BASED ON THIS SECTION OF WELDING AND ON WELD A-1
BOTTOM OF BAR BEFORE WELDING
BOTTOM OF BAR AFTER EACH WELD WAS COMPLETED.
RIGIDITY OF TACK "C" PREVENTED A UNIFORM PULLING TOGETHER OF FAYING SURFACES AT THIS END.
A-1
B-1
AMOUNT FAYING SURFACES ARE PULLED TOGETHER IN INCHES.
.10 .09 .08 .07 .06 .05 .04 .03 .02 .01 0
3 6 9 12 15 18 21 24 27 30
TOP OF CHANNEL
LENGTH OF SPECIMEN IN INCHES.
12" CHANNEL
A-1
B-1
1" x 2"
TACK "C"
PROCEEDURE-
(a) BAR LIGHTLY TACKED AT EACH END WITH A GRADUAL SLOPE FROM LEFT TO RIGHT.
(b) READINGS TAKEN WITH DEPTH GAGE THROUGH HOLES SHOWN IN BAR BEFORE WELDING, ALSO AFTER EACH LAYER HAS COOLED.
(c) WELDS MADE CONTINUOUS IN TWO LAYERS IN THE FOLLOWING SEQUENCE A-1, B-1.
3-2534
PLAN OF SPECIMEN
HOLES FOR DEPTH GAGE
TACK
EACH LAYER COMMENCED AT THIS END

Fig. 5. Diagram showing amount faying surfaces of metal arc welded lap joints are pulled together by the use of continuous welds—two layer full

Test Procedure

Pieces of tungsten steel 5/8 in. x 1¼ in. x 2 in. long, 7/8 in. x 1¾ in. x 3 in. long, 1¼ in. x 2 in. x 4 in. long and 2¼ in. x 2¼ in. x 4 in. long were flash welded to medium carbon steel shanks having a corresponding sectional area, the tools forged, tempered and service tests made.

Conclusions

This method of manufacturing lathe and planer tools and the salvaging of broken tools can be readily performed on our present equipment, the cost of manufacturing such tools being approximately only one-third that of tools made of solid tungsten steel.

GAS WELDING

TEST NO. III

To determine the strength of Tobin and Manganen bronze welds in cast iron.

Reason for Test

To obtain permission from one of our customers to use Tobin bronze filler metal instead of cast iron filler metal in the repair of defective castings so as to eliminate or reduce preheating to a minimum, thereby reducing the time and cost of welding and the liability of cracking a complicated casting.

Test Procedure

Cast iron rods 1½ in. in diameter were specially poured in the foundry, a double "V" butt joint used and welds turned off flush with base metal, 1⅛ in. in diameter.

Conclusions

Test results (Table I) are comparable with those of other investigators in that they show that such welded joints have a high strength. In all cases (Table I) they are higher than that of the base metal.

TABLE I

Test of cast iron specimens welded with the gas torch using Tobin and manganese bronze filler metal.

Specimen	*Elastic Limit (lbs. per sq. in)*	*Ultimate Strength (lbs. per sq. in.)*	*Location of Fracture*
Base metal	14,220	18,260	
Tobin bronze weld	18,910	18,910	Base metal 1" from centerline of weld.
Tobin bronze weld	18,800	18,800	In fusion zone.
Manganese bronze weld	18,680	18,680	Base metal 1" from centerline of weld.

METAL ARC WELDING

TEST NO. IV

To determine whether fillet welds made by the metal arc will pull the faying surfaces of lap joints in intimate contact, and if not, to what extent.

Reason for Test

To convince the inspection force of one of our customers that it was not necessary to pull the faying surfaces of metal arc welded lap joints as close together, prior to welding, as required for riveted joints.

Test Procedure

Strips of metal 2 in. wide, 3/8 in., 1/2 in. and 1 in. thick were assembled and welded on 6-in. and 12-in. channel sections as per Figs. 3, 4 and 5. Feelers were used for Fig. 3 and a depth gage for Figs. 4 and 5 to determine the pulling together of the faying surfaces.

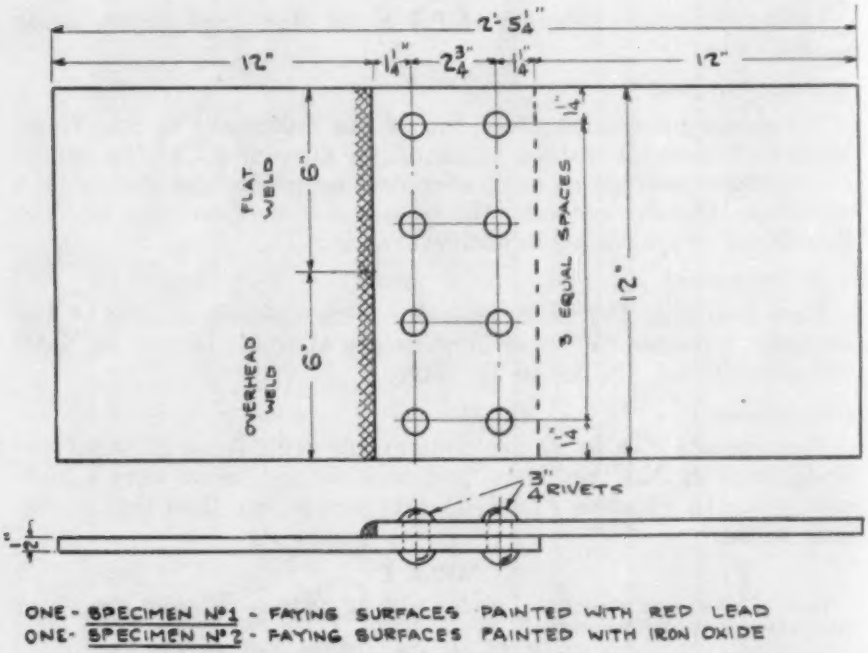


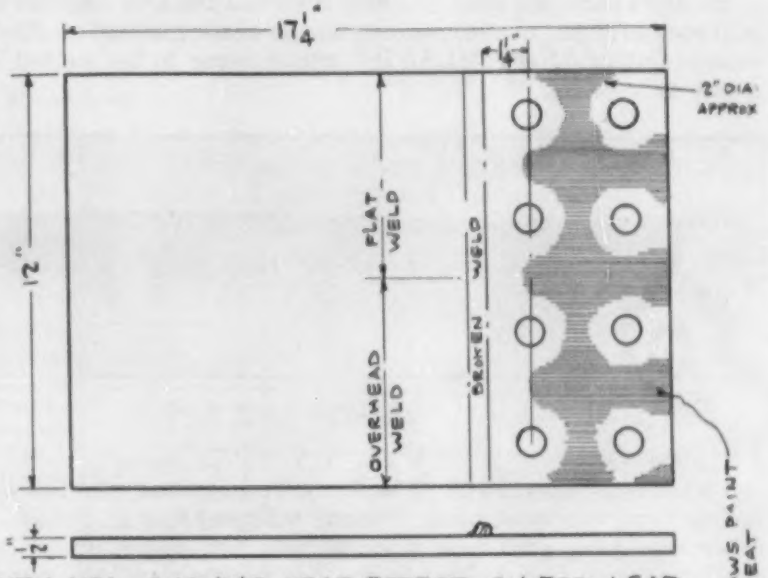
Fig. 6. Detail of specimen to determine the heat effect of metal arc welding on paint between faying surfaces of lap joints

Conclusions

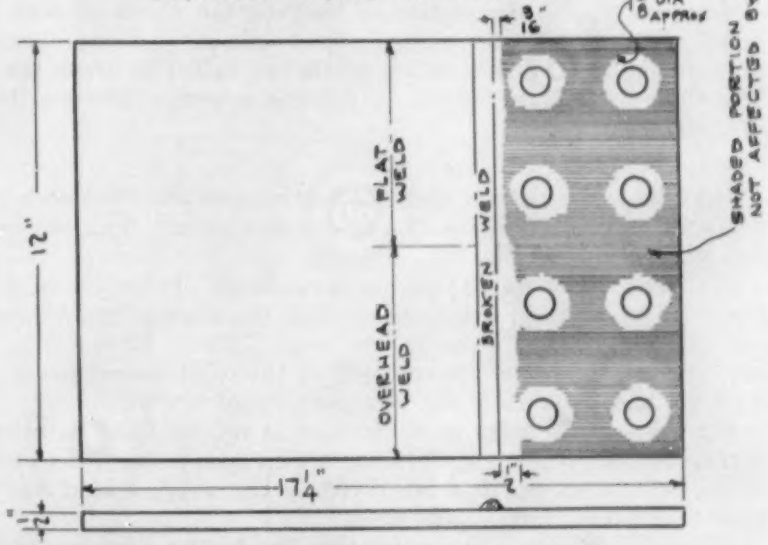
Intermittent and continuous fillet welds will progressively pull the faying surfaces of a joint together. An intermittent fillet weld pulls them together approximately 0.005 in. per linear inch of joint, as shown by a 3/8 weld, and a continuous fillet weld approximately 0.012 in. per inch welded, as shown by 1/2 and 1-in. welds. A second layer compresses the first layer of a continuous fillet weld approximately 0.0003 in. per linear inch welded, thus further pulling together the faying surfaces this amount. The

maximum pulling together of the faying surfaces is effected by the first layer of the first fillet weld.

NOTE: The customer required the use of a 0.015 in. feeler. A 0.030 in. feeler should have been satisfactory.



SPECIMEN Nº1- SHOWING HEAT EFFECT ON RED LEAD BETWEEN FAYING SURFACES.



SPECIMEN Nº2- SHOWING HEAT EFFECT ON IRON OXIDE BETWEEN FAYING SURFACES.

Fig. 7. Specimens, Fig. 6, on completion of welding showing heat effect on paint between the faying surfaces

TEST No. V

To determine the relative effect on welding conditions of red lead and iron oxide paint between the faying surfaces of lap joints.

Reason for Test

To determine the most suitable material for painting the faying surfaces of four riveted seams of the shell plating of the Coast Guard Cutter "NORTHLAND," which were to be welded subsequent to riveting.

Fig. 8. Twisted Thermit welded specimen

Test Procedure

Two riveted specimens (Fig. 6) were prepared, the faying surfaces of one specimen being painted with red lead and those of the other specimens with iron oxide paint. Six inches, or one-half of each specimen, was welded in the flat position and the remaining 6 in. in the overhead position. Two layers and 3/16-in. electrodes were used. Upon completion of welding the rivets of both specimens were cut out with a chisel, the joints given forty blows with a 12-lb. sledge, which bent the joints but failed to break the weld. The weld was finally broken by driving a wedge between the faying surfaces.

Conclusions

(a) The welding heat does not destroy the paint between faying surfaces of riveted joints to any greater extent than the heat of driven rivets. See Fig. 7.

(b) Welding of joints thus painted should preferably be done in positions other than overhead so that the oil binder will not run out and cause blow holes in the weld. These blow holes, while not seriously affecting the strength of the weld, nevertheless would tend to cause an erratic arc and porosity of the weld.

(c) Iron oxide paint is preferable to red lead for painting the faying surfaces of riveted joints which are welded, because less of the protecting paint is destroyed by the welding heat and overhead welds have fewer blow holes.

NOTE: It is unnecessary to paint the faying surfaces of joints which are completely welded.

TEST No. VI

To determine the most suitable form of joint and technic for the

welding of 1½-in. steam pipe lines with the metal arc.

Reason for Test

The elimination of slight porosity obtained in the metal arc welded joints of the fuel oil heating systems on Dieselized ships and which it is in general necessary to weld in unsatisfactory locations.

Test Procedure

A series of 1½-in. pipe sections, 12 in. long, were welded together. Both the closed and open butt joints were used. Two layers of weld metal were deposited, each one starting at the top of the joint working downwards on one side and up the other side,

REFERENCE ONE LAYER	REFERENCE TWO LAYER	INVESTIGATOR	SKETCH OF SPECIMEN	NO. OF SPECIMENS TESTED ONE LAYER	NO. OF SPECIMENS TESTED TWO LAYER	AVERAGE ULTIMATE STRENGTH WELD METAL lbs./in.²	ELECTRODE BARE	ELECTRODE COVERED	REMARKS
A_1		R.A. STORM Morgan Eng Co.		30		51175	X		TEST REPORTED BY R.A. STORM IN A.W.S. JOURNAL JAN. 1926
B_1		E.S. Humphreys UNION COLLEGE		x		36100	X		TEST REPORTED BY F.P. McKIBBEN AND W.L. WARNER IN A.W.S. JOURNAL OCT. 1924
C_1	C_2	H.E. GROVE METRO. GAS Co. Melbourne, Australia		32	5	32100 36240		Q.A.	TEST REPORTED BY H.E. GROVE IN A.W.S. JOURNAL JAN. 1927 FIG. 3
D_1		Do.		30		29930		Q.A.	Do. FIG. 1
	E_2	Do.		12		32000		Q.A.	Do. FIG. 3
F_1	F_2	Do.		3	6	32600 31500		Q.A.	Do. FIG. 5
G_1	G_2	Do.		3	6	30000 43680		Q.A.	Do. FIG. 6
H_1	H_2	Do.		6	6	58200 60000		Q.A.	Do. FIG. 8
K_1	K_2	UNION COLLEGE STUDENT		3	3	29320 41603	X		TEST DATA FURNISHED BY W.L. WARNER
L_1	L_2	Do.		x	x	29320 28000	X		Do. 1 LAYER WELD ⅝" 2 " " 1"
M		Jos. W. Owens N.N.S.&D.D.C.		3		41500	A.W.S. E-NP 18		TOP WELDS ⅜" REINFORCED BOTTOM WELDS ⅜"
N		Do.		2		42600	Do.		TOP WELDS ½" REINFORCED BOTTOM WELDS ⅜"
O_1		Do.		3		43130	Do.		TOP WELDS ¼" REINFORCED BOTTOM WELDS ⅜"
P_1		Do.		2		34500	Do.		TOP WELDS ⅜" REINFORCED BOTTOM WELDS ⅜"
R_1		Do.		2		38000	Do.		TOP WELDS ⅝" REINFORCED BOTTOM WELDS ⅜"

Fig. 9-a. Key to average ultimate strengths of fillet welds per linear inch, obtained by various investigators. Results shown in Fig. 9-b

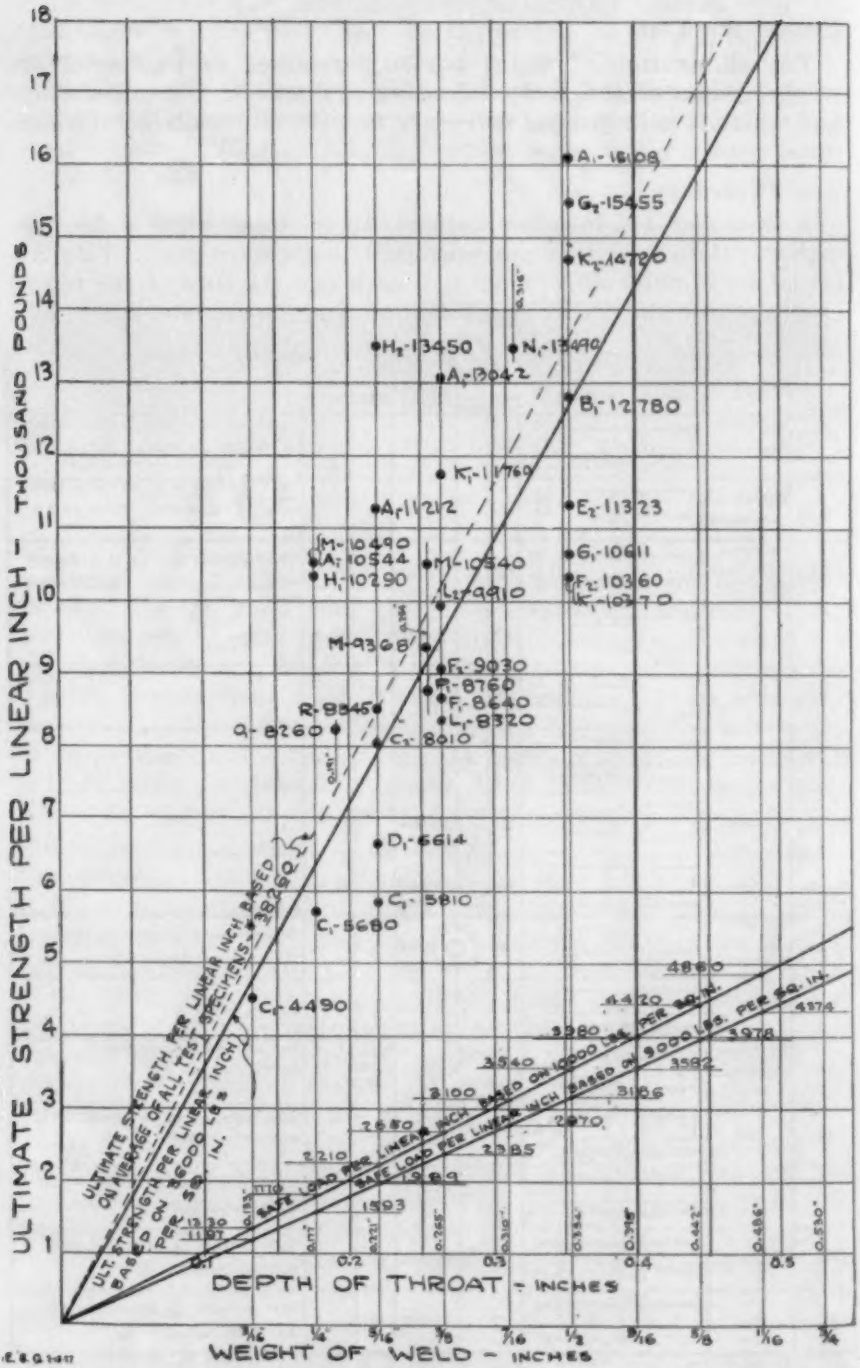


Fig. 9-b. Average ultimate strengths of fillet welds per linear inch, obtained by various investigators

by various investigators. Results shown in Fig. 9-b

completing the weld at the point of starting. The welded sections were tested with hydraulic pressure of 100 lb. and the slight porosity found in a few joints was readily stopped by peening. Pressure was then raised to 2000 lb., without any more porosity being evident.

Conclusions

(a) The closed butt joint is preferable to the open butt on pipes of small sizes because it eliminates "icicles" on the inside of the pipe and permits an inter-mingling of the base metal on both sides of the joint with the possibility of reducing porosity to a minimum.

(b) The makes of electrodes used did not materially influence the porosity obtained in the weld. Porosity was usually found in the metal deposited in the overhead position; however, all porous spots can be and were readily stopped by peening.

TEST NO. VII

To determine whether blow holes can be eliminated in cast iron welds by the use of carbon and metal arc welding.

Reason for Test

After several trials it was found impossible to entirely eliminate blow holes in gas deposited metal in the repair of cracks between the valve seats of gas engine cylinders.

Test Procedure

Standard cast iron flanges were provided with countersunk holes, preheated and the holes filled in by the metal arc using ingot iron, low carbon steel and cast iron electrodes, also with the carbon arc using cast iron welding rods. The flanges were slowly cooled in lime.

Conclusions

All welds had some blow holes, there being no decided improvement over the gas welds except possibly that deposited with the metal arc using ingot iron electrodes. The weld metal and the metal in the fusion zone of all specimens was soft and machinable except that deposited with cast iron electrodes and the metal arc.

THERMIT WELDING

TEST NO. VIII

To show that a regular thermit weld will satisfactorily resist torsional stresses.

Reason for Test

Education of the personnel and customers of our Company in the ability of thermit welds to resist torsional stresses.

Test Procedure

Two pieces of medium steel 2 in. square and 18 in. long were thermit welded and twisted in a machine lathe, as shown in Fig. 8.

Conclusions

This test and similar tests shown the writer by the Metal and

Thermit Corporation would indicate that regular thermit welds will satisfactorily resist torsional stresses without reinforcement.

CORROSION TESTS

TEST NO. IX

To determine the corrodibility of spot welds in galvanized iron (Test No. I) when subjected to the action of salt water.

Reason for Test

To convince one of our customers that the removal of the zinc by spot welding would not materially increase corrosion and thus the life of the welded joints of vent ducts.

Test Procedure

A sample was placed in sea water at tide level so as to be alternately exposed to the air and submerged in the water.

Conclusions

Test to date, over a period of two months, indicates that such welds are not subject to appreciable corrosion. Period of test is, however, too short to form any definite conclusions.

TEST NO. X

To determine the corrodibility of tobin bronze welds in cast iron, when subjected to the action of salt water.

Reason for Test

To determine whether tobin bronze welds can be used on castings subject to the action of sea water.

Test Procedure

Samples were placed in sea water at tide level so as to be alternately exposed to the air and submerged in the water.

Conclusions

Tests to date, over a period of two months, indicate that such welds are not subject to appreciable corrosion. Period of test is, however, too short to form any definite conclusions.

TEST NO. XI

To determine the corrodibility of welds in medium steel made by the gas and metal arc processes when subjected to concentrated sulphuric acid.

Reason for Test

To determine the advisability of using fusion welding instead of riveting in the construction of sulphuric acid containers for the company's storage of this liquid for galvanizing purposes.

Test Procedure

Single V butt welds were made in $\frac{3}{8}$-in. medium steel plate by the gas and metal arc welding processes. Some specimens were hammered and some unhammered. In all cases the weld metal was ground flush with the surface of the plate in order to readily observe corrosion. Specimens submerged in concentrated sulphuric acid for a period of two months.

Conclusions

As there was no indication of appreciable corrosion of the base

metal or any gas or metal arc weld after being submerged in sulphuric acid for a period of two months, containers were constructed by fusion welding instead of riveting. Metal arc welding being used.

MISCELLANEOUS TESTS

TEST NO. XII

To determine the closest distance that standard rivet holes can be punched to the edge of plates of varying thicknesses.

Reason for Test

Assembly holes being frequently necessary for the proper assembly of lap joints, it is desirable to know the minimum lap which it is possible to obtain, overlap being dependent upon the distance of the assembly hole from the edge of the plate.

Conclusions

Results of this test were reported in the April, 1926, issue of the JOURNAL OF THE AMERICAN WELDING SOCIETY.

SOME TESTS NOT REPORTED

Some of the researches and tests which have not been given in this résumé because of incompleteness or other reason, cover:

(a) Tests to determine the most suitable size of electrodes, current values and number of layers for fillet welds made in the flat and overhead positions.

(b) Tests to determine the mechanical strength of typical metal arc welded joints used in ship construction. Some of these tests are given in Fig. 9.

(c) Tests to determine the best technic for the deposition of weld metal in fillet welds.

(d) Tests to determine the strength of various forms of joints having approximately the same weight and continuity of weld.

(e) To determine the mechanical strength of metal arc welds made with and without an appreciable reactance in circuit, current being obtained from a 1000 ampere constant potential motor generator set. As a result of this test nearly all of our individual welding circuits have been provided with reactance coils and eventually all will be thus equipped.

(f) Tests to determine the utility of magnets for pulling together the faying surfaces of joints.

SERVICE TESTS OF WELDED STRUCTURES

In the last analysis, cost of manufacture and service tests of welded structures will determine to what extent welding will replace riveting and the welding process or processes most suitable for a specific job. In this connection some of the welding developments of the company were reported in the January, 1927, issue of the JOURNAL OF THE AMERICAN WELDING SOCIETY, and we will await with interest the results of their service tests.

As there was no indication of appreciable corrosion of the base

Resistance Line Welding*

H. W. TOBEY†

Resistance welding, broadly speaking, is divided into three general groups or classes—i.e., butt welding, spot welding and line welding.

Each depends for its operation, as the name implies, upon the resistance of the path along which the current is to travel, upon the volume of current, the mechanical pressure and time. The kind, quality and dimensions of the material to be welded and shape, size and characteristics of the electrodes also have an important bearing on the problem.

In the case of butt welding, the two pieces of metal are placed one opposite the other with their surfaces in contact. Sufficient current is passed through them from one to the other to bring the adjoining parts to a plastic temperature, while at the same time the pieces are forced together under mechanical pressure and are thus united or welded. The heat developed depends upon the resistance of the current path, the current, the pressure and the time.

In flash welding, which is a special form of butt welding, voltage is applied before the pieces come into intimate contact. As the advancing portions meet each other, arcing or flashing occurs and intense heat is developed at the points of contact. The projections soften or burn away and allow the pieces to come still closer together, so that other contacts are formed. Rapid progressive flashing and heating occur until the opposing sections become plastic. Quickly applied mechanical pressure forces the two parts together and what is termed a flash weld results.

In this form of welding the heat generated by the passage of current through the normal resistance path is augmented by that developed by the progressive flashing and arcing of the contact surfaces.

Spot welding, as the term implies, means the joining together of two or more pieces of metal in individual areas or spots. As ordinarily employed, the pieces to be welded are lapped one over the other, or in some instances butted together, while the electrodes carrying the current are placed one against one side of the structure and one against the other.

Sufficient current is passed through the sheets or plates to bring the material directly beneath the electrodes to a plastic condition, while at the same time mechanical pressure merges the metal together within this restricted area and a spot weld results.

With some metals having a narrow plastic range, the current may even cause actual fusion.

Here, again, in spot welding as in butt welding, resistance, cur-

*Presented at March Meeting, New York Section, A. W. S.
†Electrical Engineer, General Electric Company.

await with interest the results of their service tests.

rent, pressure and time are all important factors.

The same applies in seam welding, which we will next discuss.

In the case of seam welding or line welding, in the usual sense of the word, one of the electrodes takes the form of a wheel or roll, while the other may be either a roll or a bar. The material to be welded, ordinarily in the form of sheets or plates, is placed between the electrodes so as to form either a lap or a butt joint.

While under suitable mechanical pressure, current is passed from one electrode through the work to the other, and at the same time relative motion is brought about between the work and one or both electrodes. In some instances, the work moves, in others the work and one electrode, while in still other cases both electrodes move, depending upon the particular application or design.

Under these conditions the adjoining pieces of work are pro-

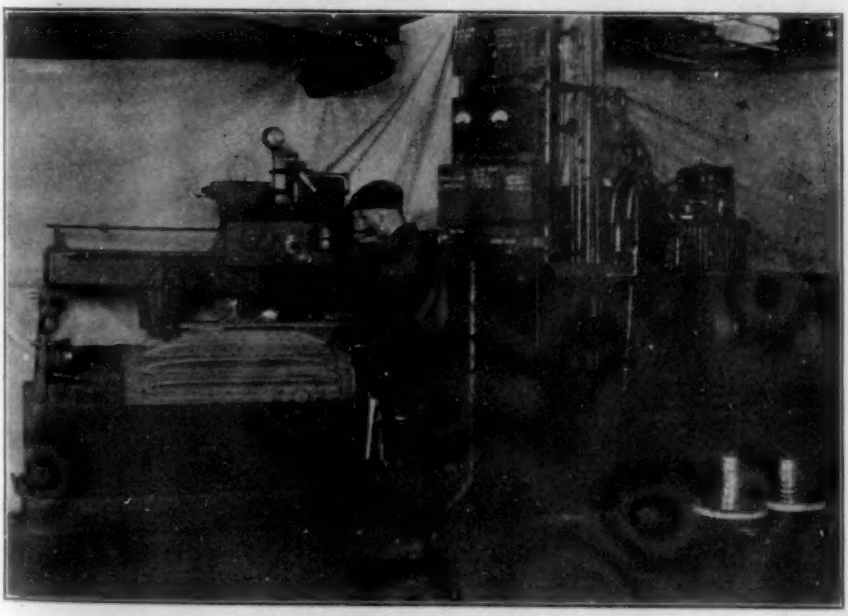


Fig. 1. Straight line resistance welding machine (work in place)

gressively brought up to a plastic temperature over a well defined area between the electrodes and a progressive or continuous line weld results.

The width and strength of this weld depend upon the current, pressure and speed adjustments as well as upon the size and shape and character of the electrodes and the shape and size and character of the metal being welded.

In general, it may be said that the width of weld increases with increase in current and decreases with increase in speed, other things being equal. Thick metals naturally require more current than thin ones for a given width of weld.

For certain classes of work, current may be delivered to the electrodes at normal commercial frequencies—60, 50, 40, 30 or 25 cycles, for example, while under other conditions it has been found desirable to periodically interrupt the current. These interruptions produce in effect a series of spots. By establishing different relations between the rate of interruption and the welding speed, the resultant spots may be made to overlap, so as to produce a continuous weld of the same general character as with uninter-

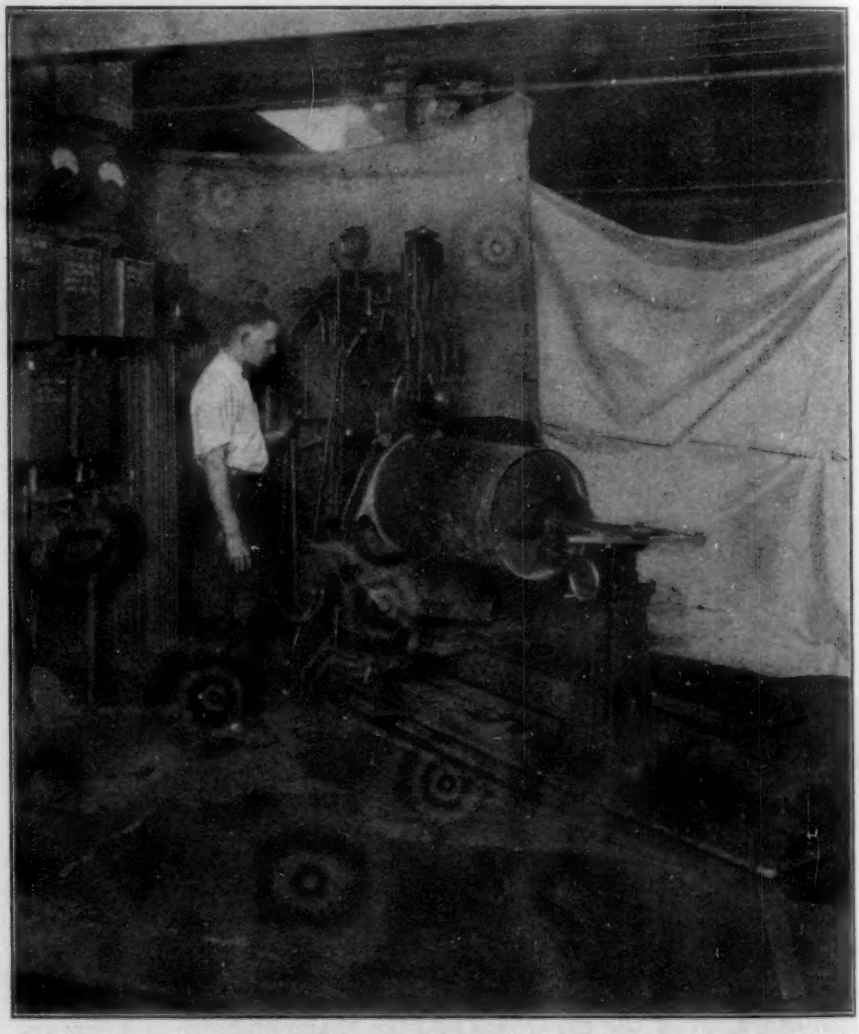


Fig. 2. Circular resistance welding machine and control equipment (work in place), front view

rupted current, or the distance between spots may be lengthened so as to produce a series of entirely independent welds.

When the metal to be line welded is of good welding quality,

clean and reasonably smooth and the surfaces make good contact, the uninterrupted or normal current produces entirely satisfactory results. On the other hand, the interrupted type of weld is desirable if the metal is rough and uneven or not thoroughly cleaned, or if the parts to be welded do not fit snugly together. Some of the poorer grades of steel and some of the alloys also weld better with the interrupted current.

Clean material always facilitates resistance line welding, and many classes of work require pickling or sand-blasting before the welding operation.

In all types of resistance welding there are characteristics of great value which should not be overlooked. The heat generated depends chiefly upon the resistance of the current path, the current, pressure and time. These factors are all under control so that after they have once been determined for a particular type of weld, the results can be duplicated with unerring regularity so

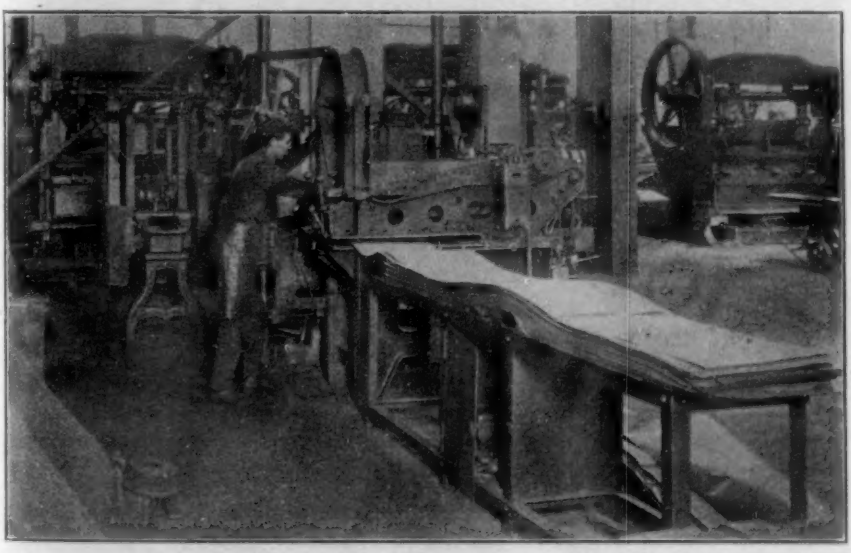


Fig. 3. Reeling and welding machine for transformer sheet steel (welding machine)

long as the characteristics of the metal remain the same. The material is brought up to precisely the right temperature, no more, no less than actually required to produce a strong, reliable weld. Uniform production is therefore assured.

Having referred to the several types or classifications of resistance welding and to some of the more important characteristics, our attention will now be turned for a few moments to specific applications of line welding and a description of several types of machines which have been designed and built and are in regular operation.

In the production of sheet steel punchings used in the construction of transformer cores, it was customary for many years to pro-

duce these in standard punch presses from mill length sheets entirely by hand feed. The speed was thus necessarily limited and a serious loss in material took place at each end of the sheet, particularly with "L" shaped punchings. The sheets ordinarily ran from 110 or 112 in. up to 120 in.

To overcome these difficulties, an automatic feed was designed for the press and a resistance line welding machine for joining the strips together into one long continuous ribbon.

The welding machine consists of one bar type electrode and one roller type electrode suitably connected to a transformer, regulator and control devices. The welding speed is approximately 240

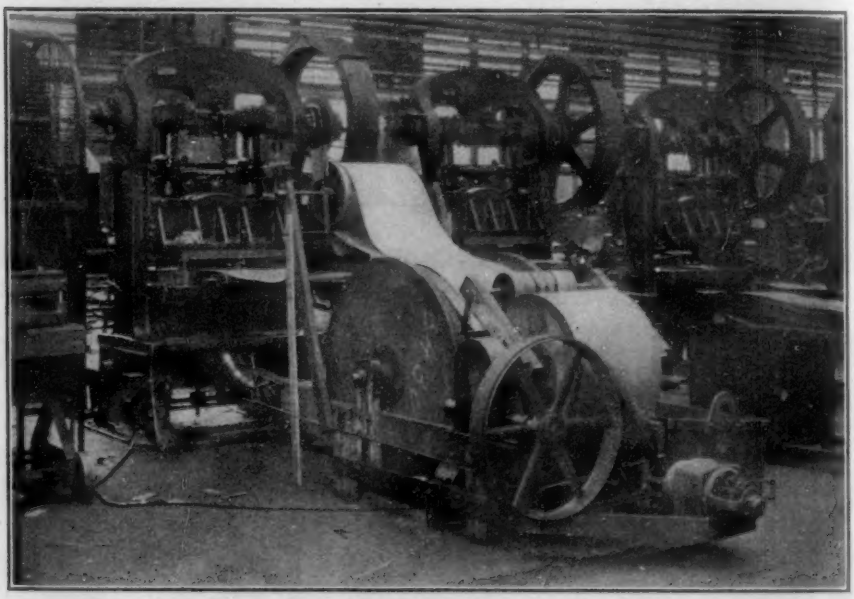


Fig. 4. Unreeling machine with welded sheets feeding steel to punch press. Hand feed

in. per minute with a current of between 3000 and 4000 amperes.

Special means are provided between the welder and punch press to allow for a reasonable amount of slack in the continuous sheet steel ribbon, so as to give the operator sufficient time to adjust the sheets and make the weld without interfering with the continuous operation of the press. The press takes up a part of the slack while each weld is being made.

As a result of these applications and other changes accompanying them, the amount of scrap has been reduced from about 35 per cent to approximately 10 per cent.

A number of these machines are in operation at the Pittsfield, Fort Wayne and Canadian plants of the General Electric Company. They furnish an excellent example of one of the many possible applications of resistance welding.

With the ever-increasing demand for lighting or distribution

transformers came the desirability, not only of constant improvements in operating characteristics, but reduction of weight as well. During earlier years cast iron had been used almost exclusively for transformer tanks. Improvements in molding and in foundry methods helped toward lighter weights, but limits in thickness were finally reached which made it unwise to proceed further in this direction.

The sheet steel tank was then developed to meet the growing demand for decreased weights. The designs called for drawn bases, rims and covers and cylindrical casings; for welded seams in the casings and between casings and rim and base. In addition to this, the larger tanks required special radiating channels or corrugations welded to the external surface. All tanks were required to be mechanically strong, oil tight and neat in appearance.

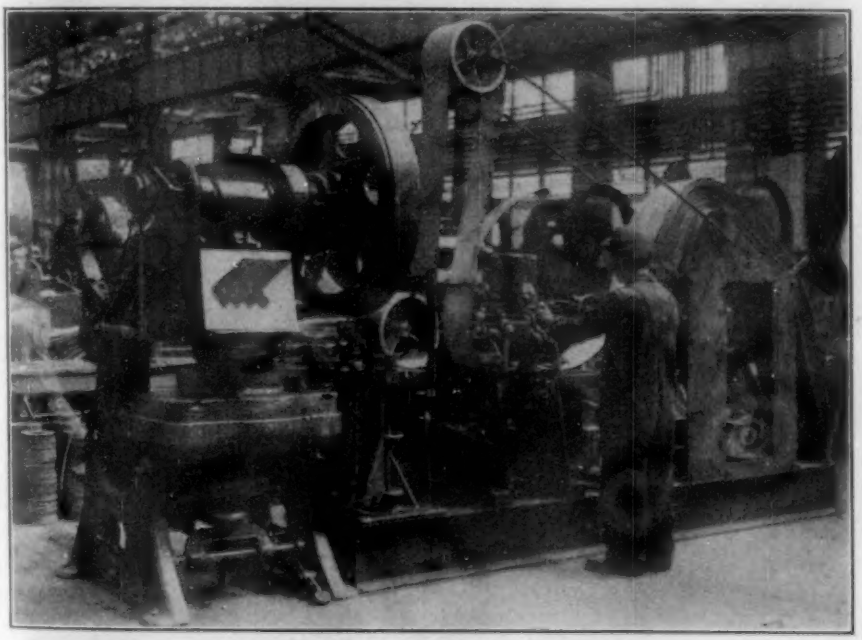


Fig. 5. Electric welding machine for welding transformer iron. Equipped with automatic feed; together with punch press

Resistance line welding seemed to best meet the several requirements and two distinct types of machine were designed for the purpose. A number of these have been built and are being used in regular production.

The straight line welder used for the longitudinal casing-seams and for welding the corrugations to the casings consists of two circular electrodes mounted one above the other in suitable bearings, which in turn are supported on carriages which travel along the upper and lower arms of the machine. These carriages are rigidly connected to a third motor-driven carriage at the rear of

the machine which carries the step-down transformer. Heavy bus-bars convey current from the secondary of the transformer to the electrodes.

Provision is made for raising and lowering the upper electrode and for applying pressure between electrodes and work while a cradle or support holds the casing in position during the welding operation. It will be noted that in this machine the work remains

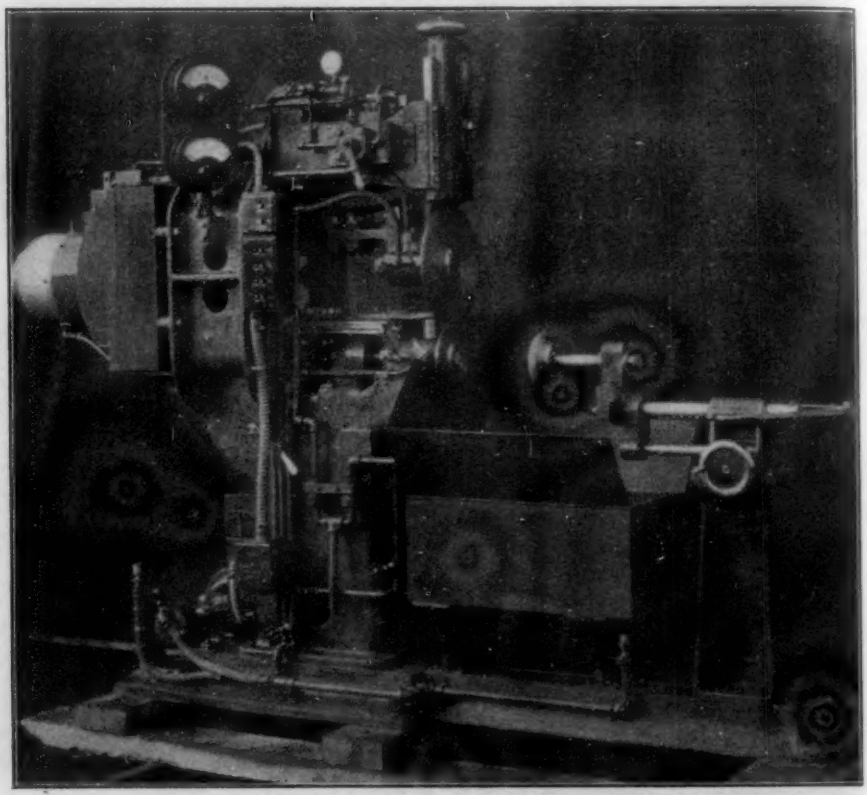


Fig. 6. Resistance welding machine (front view)

stationary while the electrodes travel along a predetermined path.

The circular line welder like the straight line machine has two circular electrodes, one above the other. The lower is supported in a stationary bearing and is motor driven through suitable reduction gearing. The upper electrode is mounted in a bearing which may be raised or lowered and pressure applied as required.

A transformer at the back of the machine supplies current to the electrodes through heavy bus-bars.

One end of the tank during the welding operation is supported on the lower electrode, while the other end rests on a roller supported by the tail stock.

In this machine, which is used for welding the bases and rims

to the casing and for welding the ends of the corrugations, the work moves while the electrodes, aside from revolving, do not change their position.

All welding takes place under water.

The currents on these machines range from 10,000 to 14,000 amperes and the speed of welding from approximately 20 in. per minute up to about 40, depending upon the nature of the work.

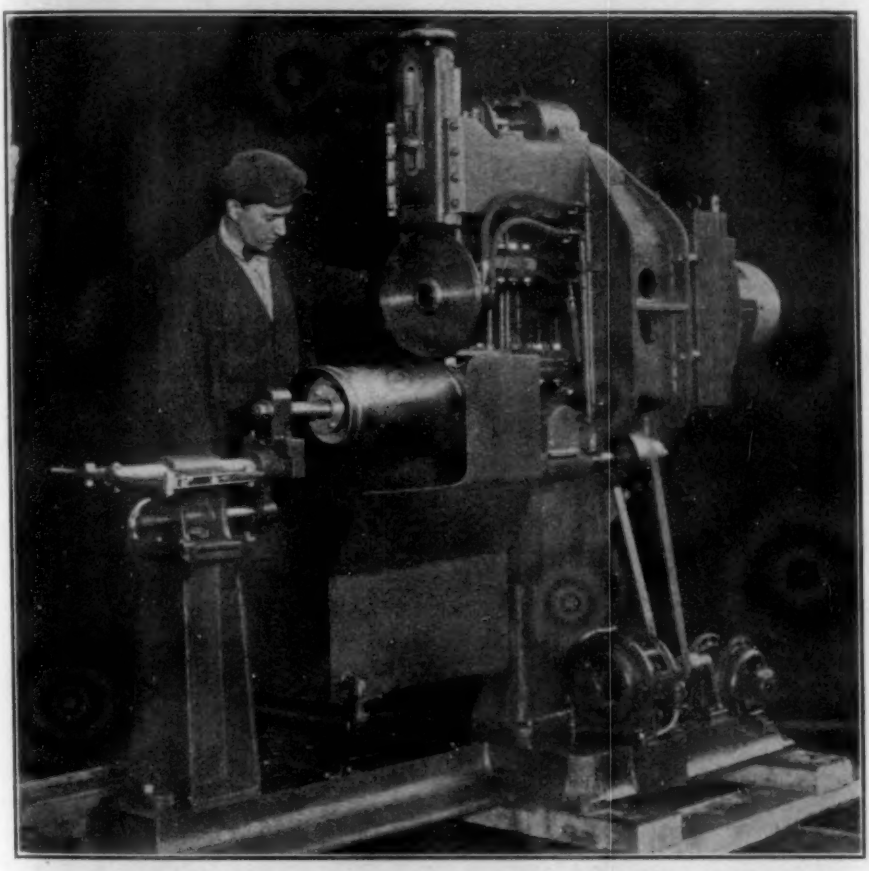


Fig. 7. Resistance welding machine (work in position for welding)

The tanks range in size from 16 in. to 21 in. in diameter and from approximately 20 in. to 50 in. in height.

The steel ranges from 3/32 in. to ⅛ in. in thickness.

Many thousands of these all-resistance-welded tanks are being turned out every year at the Pittsfield and Fort Wayne plants of the General Electric Company, where the machines are in daily operation. These installations and the quantity and character of the work turned out furnish another example in the application of resistance welding to large manufacturing problems.

Modern Structural Industry Demands a Knowledge of Arc-Welding

C. J. HOLSLAG†

The arc-welded joint can be made to possess 100 per cent strength and efficiency, and this fact alone is a valid reason why the welding process should be widely adopted. The arc-welded joint has now been so successfully tested and applied in actual building and even bridge-construction, and so many firms have found its use a practical economy, that it would seem that now is the time for publicity to make its application universal.

The amount of metal that has to be deposited in order to make a 100 per cent joint is not excessive. As a matter of fact, even in the present stage of development its cost is less than other processes. The amount of deposited metal that would be required to provide the strength of the original material, whether shear, tensile, bending, compression or alternating stress, may be very easily figured from the fact that accepted tests of the tensile strength of the welding metal show 50,000 to 60,000 pounds, and a shear stress of 30,000 to 40,000 pounds per square inch. These figures may be readily substantiated by reference to the Wirt-Jones test, made by the American Bureau of Standard and published by the American Welding Society or to the test made by the General Electric Company, in collaboration with Union College; or to the results of the Westinghouse tests, and to the test made in Melbourne, Australia, by the Metropolitan Gas Company's Engineering Department. This latter test, by the way, was the most elaborate yet attempted, and the results, which are excellent, are given in the January, 1927, issue of the *Journal* of the A. W. S.

As far as assembling details are concerned, welding provides the utmost flexibility and convenience. Attaching plates and turnbuckles, when they have served their purpose, are simply knocked off with a blow at right angles to the line of weld. In short, these temporary jigs and fixtures are purposely made weak only in the unimportant direction, and strong only in essential and important direction.

The American Bridge Company is rebuilding a large span at Leavenworth, Kan., and using arc welding to do it. Bridge welding, of course, is not the simplest and most obvious kind of welding. The best place to learn welding is in the shop—on window frames, door frames and odd pieces, repairs, etc. In actual building construction the roof might perhaps seem the logical place to start, because on the roof work the welding process shows prompt results, both in speed of work and in cost saving to the builder. This holds true for both gas and electric welding.

---

*Manager, Electric Arc Cutting & Welding Co.
†To be presented at Annual Meeting, A. W. S.

The advantages of structural arc welding have received publicity by reason of the fact that various welding apparatus companies have built and tested experimental buildings, roof trusses, etc. What of buildings, however, that are designed not for experiment but for actual everyday service? This article deals primarily with

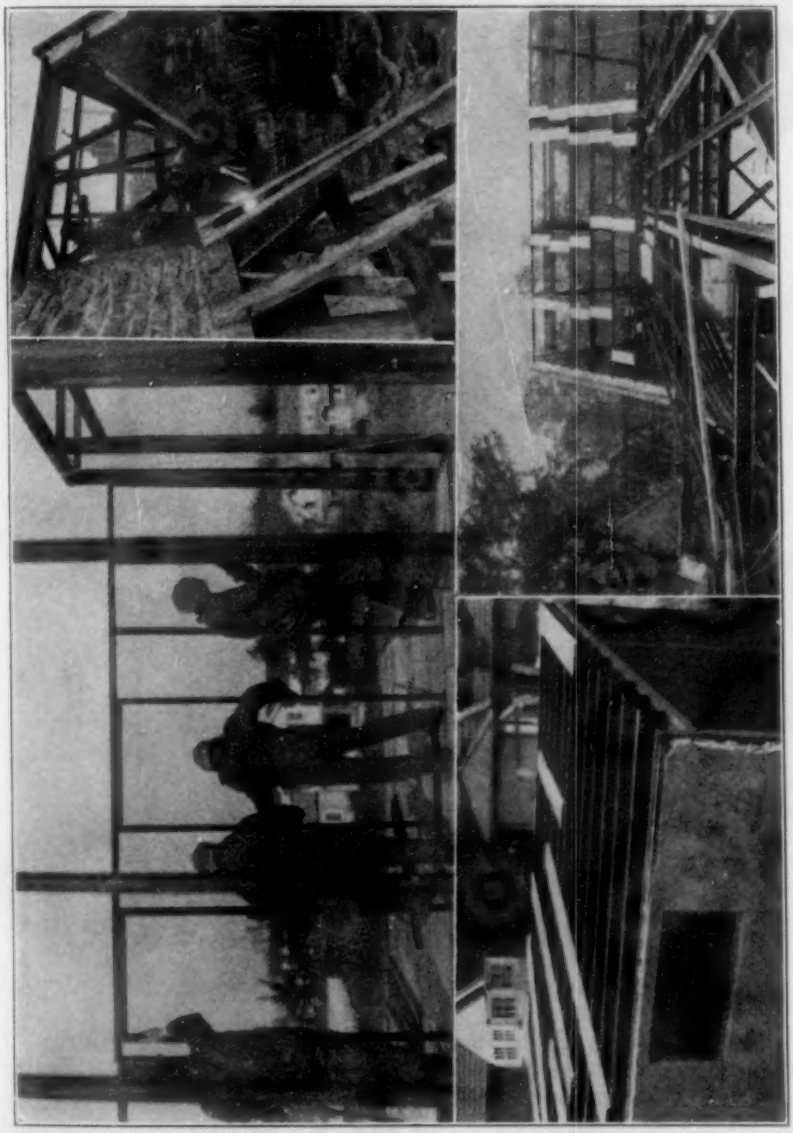


Fig. 1. Welding used extensively in building construction. Upper right, welding roof purlins in place

arc-welding structural work that is in actual service after acceptance by civic and state authorities. The photos are real buildings, no experiment, I hope.

In this connection I may mention the roof truss that was shown arc welded by the Electric Welding Company of America and which was approved by the New York City authorities several years ago. Again, I may mention buildings erected by the General Electric Company, the Lincoln Company and the Westinghouse, as well as by ourselves. The buildings were all made with standard structural shapes, not all of which fit readily into the scheme of electric arc welding.

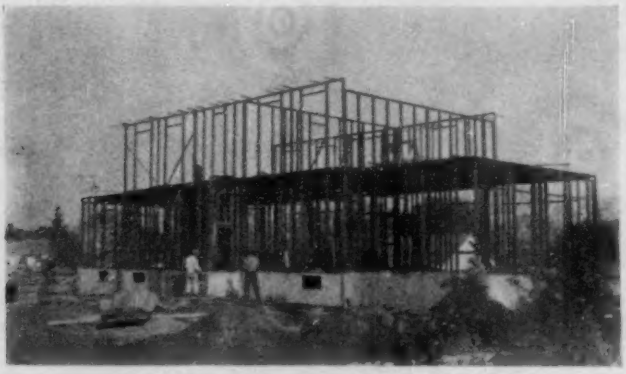


Fig. 2. Welded residence in process of erection

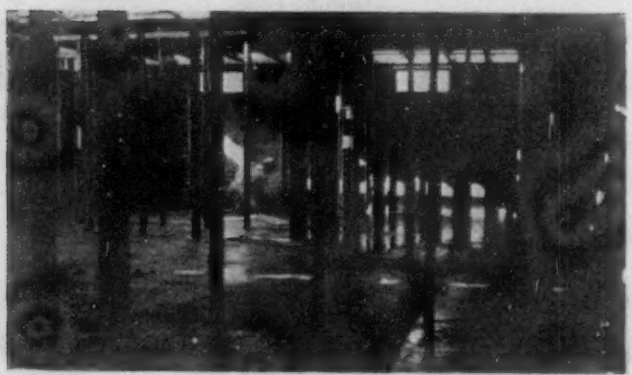


Fig. 3. Welding used in residence construction

It may come as a shock to those who adhere to earlier ideas of steel practice, to learn that webs of angles, channels and I beams are not always necessary and that the strength can best be met by other means. As an instance of this may be cited the structure put out by the various people making these new bar joints. This truss is practically made of rods, welded together. The bottom and top chords, as well as the struts, are ingeniously formed out of bent rods, arc welded together. Where they meet at each end they

are joined by the same process to a standard structural shape. This truss, by the way, is a real truss of the Pratt type, and when used with concrete or steel as a floor or ceiling it produces a most economical construction.

A further proof of the value of the arc-welding process I might point to about thirty buildings here in the metropolitan section among which is a completely welded house at No. 766 Carrol Place, Teaneck, N. J., made by Jos. J. Dudley of the Weldcrete Company and the Electric Arc Cutting and Welding Company. The house is very similar to that of the wood-frame type, except that steel alone is used. It was built from flat and standard sections which were lifted into place and the sections welded together. All cutting on this job was also done with the arc.

Fig. 4. Completing roof construction for U. S. Gypsum Co. building

Another building embodying only welded construction is being erected at 152-156 Jelliff Avenue, at the plant of the Electric Arc Cutting and Welding Company. The roof is made with the standard trusses of the Concrete Steel Company, the columns are welded Lally columns, which for years have been accepted as standard by all authorities and are made entirely by welding. The special frame at cap and base is nicely adapted by this process. In short, wherever a joint occurs, it is made by the welding process.

Still another beautiful adaptation of arc welding lies in the attaching of roof purlins to the rafters, where a fireproof slab roof is used. Such a one is submitted by the U. S. Gypsum Co. or the Porete Mfg. Co. The standard T bars, formerly drilled, bolted or tapped in place, by hand, on the roof, are replaced by simply cutting and fitting the pieces and tacking them in place by arc welding. A single welder is able to attach in this way as much steel as a whole gang of iron workers. When it is realized that on gable roofs practically every piece has to be fitted in place on the job the advantage of welding is obvious.

A list of buildings in this vicinity that have been welded in this way follows:

Eighty-sixth Street and First Avenue—Theater—New York City.

Fordham Road and Jerome Avenue—Theater—New York City.

Mt. Morris Avenue and 186th Street—Theater—New York City.

Mt. Eden Avenue and 176th Street—Theater—New York City.

Eighty-sixth Street and Lexington Avenue—Theater—New York City.

Parkway Baths—Brighton Beach.

Loew's Theater—Main Street, White Plains, N. Y.

Loew's Theater—Main Street, New Rochelle, N. Y.

Masonic Temple—North Broad Street, Elizabeth, N. J.

Marcus L. Ward—Home—70,000-ft. roofing—Maplewood, N. J.

Bound Brook Theater—Bound Brook, N. J.

New Maplewood Theater—Maplewood, N. J.

Holstead Theater—South Orange Avenue, Newark, N. J.

Moving Picture Theater—Stuyvesant and Morris Avenues, Union, N. J.

Colonel Rogers' Hunting Lodge—Southampton, L. I.

The apparatus with which this work is done is incidental and any machine may be used. In the building at Teaneck, mentioned above, AC was used, two and four machines being operated from one line transformer. In the Porete installation generators made by the writer's company were used. In the U. S. Gypsum installation generators of various makes were used. Some were motor driven, others were gas-driven. In general, where there is electric power available, it pays to have a separate meter put in for the welding.

New York is not the only city to use this process. Other cities have fallen into line, especially Cleveland and Detroit. In other words, the idea of structural arc welding is a national idea, not a local one. It is not necessary, of course, to go to the extent of putting up a building in order to use structural welding to advantage. There are thousands of other needs. It may be used in the shop and in the field. In design, in piecing out and joining members together to fit special needs; iron work, ornamental, special, etc. In such cases welding will pay for itself many times over. The first structural welding ever done that I know of was at the Erie plant of the General Electric Co. in April, 1918. This was a complete electric locomotive cab, frame, windows and doors and apparatus brackets and is still being operated.

Building alteration is being done and has been done in various cities by the electric arc process. The Foundation Company has just completed a very imposing task of this kind on the interior steel structure, boiler framing, etc., of the Prudential Building at Bank and Broad Streets. Arc cutting and welding was used ex-

tensively on this job; the cutting to remove parts and the welding to fit them and replace them.

The capabilities of electric arc-welding are more perfectly adapted to structural work in metal than perhaps to any other single industry. There is no imaginable form of steel structure, large or small, that could not advantageously be put together by welding. Not only does welding offer the structural industry greater facility, efficiency and durability in the results it produces, but it accomplishes these results at an appreciably lower cost and this applies not only to all steel construction but to any construction in which metal is joined and where the joint is required to be strong, tight and lasting.

The peculiar qualities of the electric arc which render the process so well suited to all forms of structural work, appear most strikingly in building construction. The most important quality to structural designers and contractors is that of rigidity, for if the joint possess rigidity and strength, the problem of designing and proportioning the entire structure may be solved with confidence.

Another important factor to be considered is the workability of the arc-process. To begin with, a single machine and its operator forms a complete producing unit which can work independently. Contrast this with rivetting in construction work. The latter demands a gang of men for punching, fitting, aligning, heating and riveting. If a single one of these steps is poorly or inaccurately done, the entire result suffers. In welding, on the other hand, the operator, the electrode and the machine, alone determine the result. When the machine is in good shape and proportioned to the work at hand, the rest depends upon the operator. A good machine helps a good operator.

A subject more fully appreciated, perhaps, is the matter of tightness of welding. Since many tanks are practically structural in design, the subject deserves a place here. Riveted joints that are required to be water, air or gas tight must be carefully filled and caulked; there is no other way out of it. On the other hand, a welded joint is by its very nature tight without caulking. There is no warping or twisting in such a joint. For this very reason welding is often used to close up already riveted seams when other methods to make a tight joint have failed, owing to the continual loosening of the rivets. It would be better to construct the joint by arc welding in the first place.

Another tremendous advantage of the electric arc in construction work is its great adaptability in creating on the spot structural shapes to meet any particular need. For this reason builders find the arc process capable of the most extended service in such a variety of applications as metal window framing, corner-angle work, metal stairways, newel posts and hand rails, doors and door framing stiffening members, chutes, hoppers, balconies, straps for holding piping and conduits, etc. These are but a small fraction of the number of uses to which this process can be put.

Workers in iron and steel of all types of products have found the arc-process universally adapted to their needs. Ornamental iron work of every nature is done more efficiently and more neatly by means of electric-welded joints. The arc in this work makes possible the smooth realization of the design with no unsightly rivets or bolts. And apart from pleasing the eye, the joint is the strongest and most durable one that can be made.

But, as electric welding is relatively new in the structural field, the designer will have to cast aside many of his prejudices (caused, originally, by the limitations of other methods) and learn to know welding. He will find, first, that his work is simplified; second, his results are less a matter of uncertainty. Let him study with an open mind some good welding handbook. Such data should be in the hands of every engineer, construction designer or user who wishes to examine honestly the advantages of arc welding.

CURRENT WELDING LITERATURE

Applied Structural Steel Welding. The Associated Technical Societies of Detroit Bulletin (February, 1927), Vol. 6, pp. 10-11.

Arc Welding. J. F. Lincoln. U. S. Pat. 1604189, Off. Gaz. (Oct. 26, 1926), 351, 762-3.

Arc Welding Equipment for Street Railways. A. E. R. A. (March, 1927), Vol. 17, p. 280. Discussion by members.

Arc Welding, Method of. V. L. Ronci. U. S. Pat. 1605071, Off. Gaz. (Nov. 2, 1926), 352, 112.

Arc Welding and Cutting, Electric. Quasi-Arc Co., Ltd., and A. P. Strohmenger. Brit. Pat. 259365. Ill. Off. Jnl. (Dec. 1, 1926), 38, 5530-1.

Autogenous Welding. Walter Constance, Railway Journal (March, 1927), Vol. 33, pp. 24-25.

Bridge Repaired by Welding. Engineering News-Record (Feb. 24, 1927), Vol. 98, p. 333.

Bronze Welding Applications. W. C. Swift, Welding Engineer (December, 1926), 11, 26-8.

Butt Welding Long Seams. Welding Engineer (December, 1926), 11, 31-2.

California Florist Builds Nursery Buildings with Welding. The Welding Engineer (February, 1927), Vol. 12, p. 22.

Cutting Metals Under Water. L. F. Hagglund, The Welding Engineer (March, 1927), Vol. 12, pp. 39-40.

Electric Arc Welding in Maintenance Work. R. E. Kinkead, Industrial Engineer (March, 1926), Vol. 85, pp. 110-12. Describes the rapid method used in mending vital parts of machinery.

Investigating Spot Welds. The Welding Engineer (March, 1927), Vol. 12, pp. 35-36.

"Let's Go" on Structural Welding. C. J. Holslag, The Welding Engineer (March, 1927), Vol. 12, pp. 31-32.

Manganese Steel, Weld. Diesel & Oil Engine Journal (January, 1927), 2, 23.

Microstructure of Welds. Prof. J. Neill Greenwood, D.Sc., The Australian Welding Engineer (Feb. 1, 1927), Vol. 1, pp. 34-35.

Oxy-Acetylene Tips (March, 1927), Vol. 5, No. 8. Stelliting Dredge Cutter. Before You Start the Job. Fold Along the Dotted Line. Welding Keeps Logs Moving. Don't Pile Money on the Scrap Heap. Record Time in Welding Door Grille. Welding and the Welding Rod. Remaking a Shaft Hanger. Using the Past to Better the Future. Internal Stresses Due to Oxwelding. From Wood Room to Fourdrinier. Sanitary Joints for Hospital Equipment. Cast Bronze Is Preheated Before Welding.

Pipe Welding Under Difficulties. George Walker, The Welding Engineer (March, 1927), Vol. 12, pp. 29-30.

Practical Oxy-Acetylene Welding. V. R. Granjon, P. Rosemberg and A.

number of uses to which this process can be put.

Desgranges, The Welding Journal (February, 1927), Vol. 24, pp. 42-45. Contains Chapter 9. Fourth Course of Exercises: Welding 11, 8 and 6 S.W.G. Sheet Steel. Chapter 10. Fifth Course of Exercises: Welding Bevelled Sheet Steel from 3/10 to ⅜ in.

Repairing Car Wheels by Welding. Railway Journal (March, 1927), Vol. 33, p. 35.

Testing Gas Welds. Prof. H. L. Whittemore, The Welding Journal (February, 1927), Vol. 24, pp. 46-48. Describes: Field, Workmanship. Research: Laboratory Tests for Welds, Non-destructive Tests for Welds. 1. The Electrical Resistance Method. 2. Magnetic Analysis. 3. X-Ray Examination.

Slack in Pipe Lines. L. A. Kelly, Acetylene Journal (March, 1927), Vol. 28, pp. 425-427.

Some Facts About Welded Joints. S. J. Melville, The Welding Engineer (March, 1927), Vol. 12, pp. 37-38.

Suggested Program for an Investigation of the Fatigue Resistance of Welds, American Bureau of Welding. H. L. Whittemore, Acetylene Journal (March, 1927), Vol. 28, pp. 434-436.

Testing the Skill of Welders. A. Desgranges, The Australian Welding Engineer (Feb. 1, 1927), Vol. 1, pp. 31-33; also in Acetylene Journal (March, 1927), Vol. 28, pp. 423-24 and 427.

The Flow of Welding Metal. J. B. Green, The Welding Engineer (February, 1927), Vol. 12, pp. 25-29. Slow motion movies, taken with infra-red light on a special film, are used to show welding qualities of filler rods. Photographing the transfer of metal. Classifying filler material. Filler rod affects every phase of weld. Mechanism of metallic arc transfer. Influence of structure. Influence of surface composition. Building of deposit metal explained.

The Most Important Thing in Welding. S. W. Miller, Mechanical Engineering (March, 1927), Vol. 49, p. 248.

Thermit Saves Time. Pacific Marine Review (March, 1927), Vol. 24, p. 141.

Torch Manipulation in Welding. The Welding Engineer (February, 1927), Vol. 12, pp. 30-33. Describes movements of the torch are not just to keep it on the jump. Every motion of torch has an effect on the weld.

Torch Uses in the Tinplate Industry—Maintenance Work on Massive Machinery. Acetylene Journal (March, 1927), Vol. 28, pp. 428-429.

Ultimate Strength of Single Vee Welds. E. E. Thum, Acetylene Journal (March, 1927), Vol. 28, pp. 430-431.

Welded Brine Cooler Explodes, Injuring Two at Fleischmann Yeast Plant. Power (March 1, 1927), Vol. 65, p. 345.

Welded Factory. The Welding Engineer (February, 1927), Vol. 12, p. 34.

Welded Joints Did Not Fail. Acetylene Journal (March, 1927), Vol. 28, pp. 432-433.

Welded Lugs for Arc Welding Cables. R. E. Kinkead, Power (March 1, 1927), Vol. 65, p. 339.

Welded Pipe Lines for Central Heating. Acetylene Journal (March, 1927), Vol. 28, pp. 419-422. A digest of two interesting articles on this subject which appear in the current issue of Industrial Gases.

Welded Steam Pipe Line. A. W. Birnie, The Welding Engineer (February, 1927), Vol. 12, pp. 39-40.

Welding and the Welding Rod. E. H. Sharp, The Welding Engineer (February, 1927), Vol. 12, p. 23. For sound welds it is essential to use best materials available; also in Pacific Marine Review (March, 1927), Vol. 24, p. 141.

Welding Lugs on Electric Cables. C. O. Mills, Power (March 8, 1927), Vol. 65, p. 376.

Welding Reduces Power House Costs. T. Eugene DePew, The Welding Engineer (March, 1927), Vol. 12, pp. 25-27.

Welding Shop Layout. The Welding Engineer (February, 1927), Vol. 12, pp. 21-22.

Welding Structural Steel. K. Haas, The Welding Engineer (February, 1927), Vol. 12, pp. 36-38. Results of tests made on structures made by riveting and structures of identical design made by welding.

Welding, Study of Autogenous Electric. H. Dustin, Rev. Univ. Mines, Metc. (Dec. 1, 1926), 12, 117-206.

Welding. Thermal Disturbance in Iron and Steel During Welding. Mechanical Engineering (March, 1927), Vol. 49, pp. 272-273.

Wrenches Made to Order. Will Stewart, The Welding Engineer (March, 1927), Vol. 12, pp. 33-34.

Practical Oxy-Acetylene Welding. V. R. Granjon, P. Rosemberg and A.

TORCHWELD LEADERSHIP

"Standard of Comparison"

Torchweld is the acknowledged leader in the gas welding and cutting equipment field because Torchweld design is original and Torchweld superior construction insures long and satisfactory service.

TORCHWELD EQUIPMENT CO.

224 No. Carpenter St. Chicago, Ill.

REGO

"LOWER OXYGEN PRESSURE"

Welding and Cutting Equipment

WRITE FOR CATALOG NO. 37

THE BASTIAN-BLESSING COMPANY

252 E. Ontario St., Chicago, Ill.

Weldite

Welding Rod

WELDITE G—No. 6 Coppered Finish for gas welding lays the metal down quietly, free from boiling, free from surface scum and floating white specks. The metal settles instantly when the torch is removed.

WELDITE E—No. 18 Green Surfaced for electric welding is the smoothest running electrode ever offered users of welding. Sold at the price of bare electrodes.

Products of the Research Department

Weldite

MANUFACTURED BY

CHICAGO STEEL & WIRE Co

103rd Street *and* Torrence Avenue CHICAGO

Wrenches Made to Order." Will Stewart, The Welding Engineer (March, 1927), Vol. 12, pp. 33-34.

HOLLUP

WELDING WIRE AND SUPPLIES

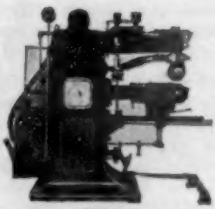
ARE UNIFORM

Out of nearly two million pounds of Hollup Welding Wire shipped during 1926 not one pound was returned because of unsatisfactory performance.

WANAMAKER COATED ELECTRODES
REX PROCESSED BARE ELECTRODES
REX OXYACETYLENE WELDING RODS
REX WELDING ACCESSORIES

C. H. HOLLUP CORPORATION
3333 W. 48th Place, Chicago, Ill.

SPOT



SEAM

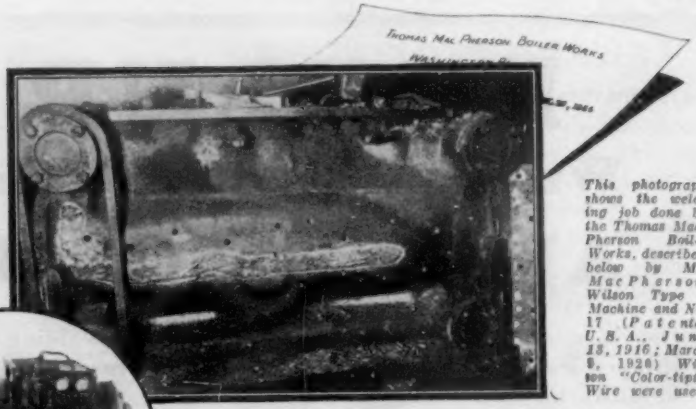
For Production
Electric Welding
Machines

ARC

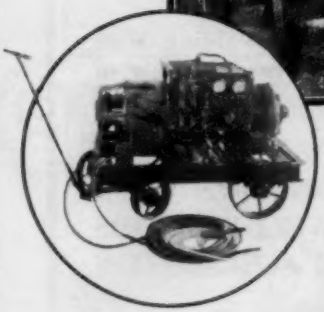
Gibb Welding Machines Company

Bay City, Michigan

New York—Philadelphia—Cleveland—Cincinnati—Detroit—Buffalo
Chicago—St. Louis—Los Angeles—Toronto—Montreal



This photograph shows the welding job done by the Thomas MacPherson Boiler Works, described below by Mr. MacPherson. Wilson Type 8 Machine and No. 17 (Patented U. S. A., June 13, 1916; March 6, 1928) Wilson "Color-tipt" Wire were used.



The above is a Wilson Type 8 Single-Operator, Motor-Driven Electric Welding Machine — designed for both production and repair work, and adapted for use wherever power is available. Its capacity is 25 to 300 amperes. Other Type 8 Machines include both single and two operator units — gasoline - engine - driven, belt-driven and motor-driven — portable and stationary. Capacities: 25-250, 25-300, 25-600 Amps.

"The Biggest Welding Job In My Experience!"

"I am enclosing photograph of the biggest welding job in my experience. The cylinder over all is 8 ft. long and 30 inches in diameter. The horizontal crack is about 6 ft. long; and that weld you see in the picture reaching up the end of the cylinder is 2 ft., making a total of 8 feet. The thickness of the cylinder wall is 1⅛ inches. I am very pleased to tell you the job is a complete success. The Wilson Welding Machine behaved splendidly. And as for the Wilson Color-tipt Welding Wire, I never would have tackled this job without it. As regards the procedure, the crack was first veed out to an angle of 45 degrees, holes drilled and ⅝-in. steel studs inserted at 1½-in. pitch. The cylinder was kept slightly hot."—T. MacPherson, Thomas MacPherson Boiler Works, Washington, Pa.

The biggest welding job in my experience! **An 8 ft. crack in a steam cylinder. A fussy job. But, experience pointed to the *sure* way—a Wilson Machine and the right grade of Wilson Wire.**

The right grade of wire for the metal, and perfect uniformity and flowing quality in each grade—that's Wilson "Color-tipt" Welding Wire! You can select just the right grade (analysis) for each weld—and every rod will be just like every other rod in the grade you select. Each grade is designated by a color, hence, "Color-tipt."

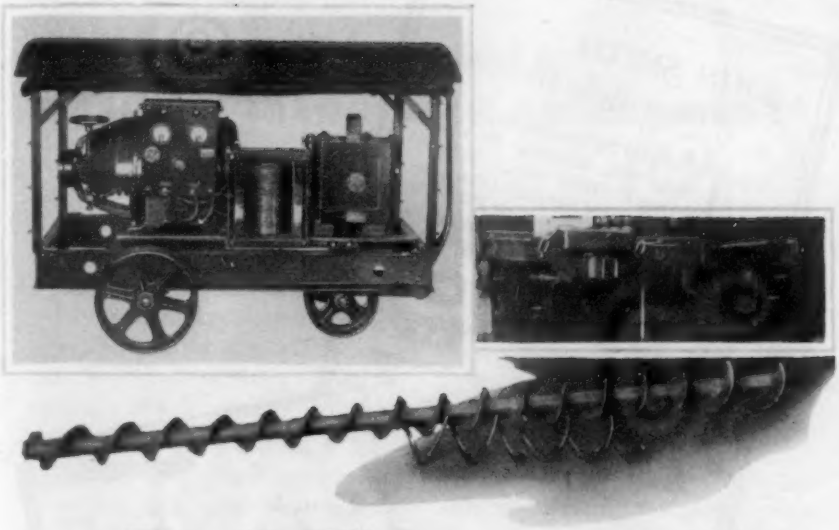
Are you profiting by the economies afforded by electric welding? And are you making possible the perfect weld? Use Wilson Machines and Wilson Wire—the right grade for the metal you're welding, of course—and the rest is up to the welder. There is a Wilson Welding Machine that meets *your* particular operating conditions—*your* particular industry. And there is a right grade (analysis) of Wilson Wire for the particular metal you are welding.

Send today for bulletins describing Wilson Welding Machines, and ask for sample of Wilson "Color-tipt" Welding Wire, indicating the kind of welding you wish to do.

WILSON WELDER & METALS CO. INC., WILSON BLDG., HOBOKEN, NEW JERSEY

WILSON

WELDING MACHINES AND WELDING WIRE



Don't Throw Away $88

A G-E Arc Welder reclaims these $100 stoker screws at a cost of $12 and, on each job, robs the scrap heap of $88.

The abrasive action of coal thins down the blades and reduces the diameter of the screw, often within six months of service. The worn screws are then brought into the repair shop. The blacksmith makes up a spiral steel reinforcing strip and tacks it in place on the conveyor. A G-E welder then makes a neat and practically indestructible weld—using 3/16" electrode and 170 amperes. The conveyor is then ready for another long stretch of service.

Walk through your repair shop and notice the hundreds of repair jobs that can be done by a G-E Arc Welder with equal ease and equal or greater savings. Then ask yourself if you have enough G-E welders to take care of all the work.

You'll find it a good habit to phone or write to your nearest G-E office any time you want welding advice or welding service.

G-E Welding Electrode when used with the G-E Automatic Welder produces strong, smooth welds at great speed.

230-230

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., SALES OFFICES IN PRINCIPAL CITIES

JOHN SMITH
of Great Falls, Montana

JOHN SMITH has a welding shop in Great Falls, Montana. He wants Union Carbide today. So does another John Smith whose plant is in Savannah, Georgia. He wants to use it NOW. He is buying Union Carbide because he knows its quality and because he can get it—quick.

John Smith knows that Union Carbide is stocked in 190 warehouses in 190 cities. He knows that an order will be shipped the same day from a Union Carbide Warehouse located near his home or place of business.

He realizes that this nation-wide warehousing and distributing system assures to Union Carbide users an immediate supply. No delays. No worry.

UNION CARBIDE SALES COMPANY

Unit of Union Carbide and Carbon Corporation

Carbide and Carbon Building 30 East 42d Street

NEW YORK CITY

PEOPLES GAS BUILDING
CHICAGO, ILL.

ADAM GRANT BUILDING
SAN FRANCISCO, CAL.

Union Carbide Warehouses in 190 Cities

What does welding inspection amount to?*

SOME ENGINEERS actually believe that you can't tell whether a welded joint is good or bad and that inspection of welds is almost useless. This is certainly far from the truth.

Take for example a demonstration of welding inspection. A shop foreman was asked to make 25 welded tanks, to be classed as "good," "fair," "poor" and "very poor." He used some of his tested welders and also hired some novices. He supervised the work in the usual way and classified the finished tanks.

These tanks were shipped to the Bureau of Standards and tested to destruction. Those classed as "good" showed an average efficiency at the joint of 102%. In other words, the joints held until the plate itself had given way. The "fair" tanks showed 85% efficiency. The "poor" tanks gave way at about 65% and the "very poor" tanks at 45%.

A competent shop foreman can spot poor work while it is being done. He can also recognize it after the welding is finished. Designers and engineers need have no fear that inspection is unreliable or inadequate in a shop operating under Linde procedure control.

Linde engineers are ready to supply you with facts concerning the elements of procedure control.

THE LINDE AIR PRODUCTS COMPANY
General Offices: Carbide and Carbon Building
30 East 42d Street, New York

37 Plants — 105 Warehouses

LINDE OXYGEN

* No. 4 of a series of advertisements on the engineering phases of oxy-acetylene welding and cutting. Send for the booklet entitled "Engineering and Management Phases of Oxwelded Construction."

Oxweld H.T. pays 20%

When you buy welding rods you expect reliability and strength in the welds you make. Oxweld rods have always given you that.

But the Oxweld No. 1 High Test steel welding rod gives a 20% dividend of strength over good grade Norway rods. A remarkable return on any investment.

One company compared hundreds of welds made by its staff of 80 welders with both H. T. welding rods and good grade Norway rods. The tensile strength of the H. T. welds averaged 20% higher! And the welding was accomplished in 20% faster time.

In some measure this explains the remarkable increase in the use of Oxweld High Test rod.

OXWELD ACETYLENE COMPANY

Unit of Union Carbide and Carbon Corporation

CHICAGO
3642 Jasper Place

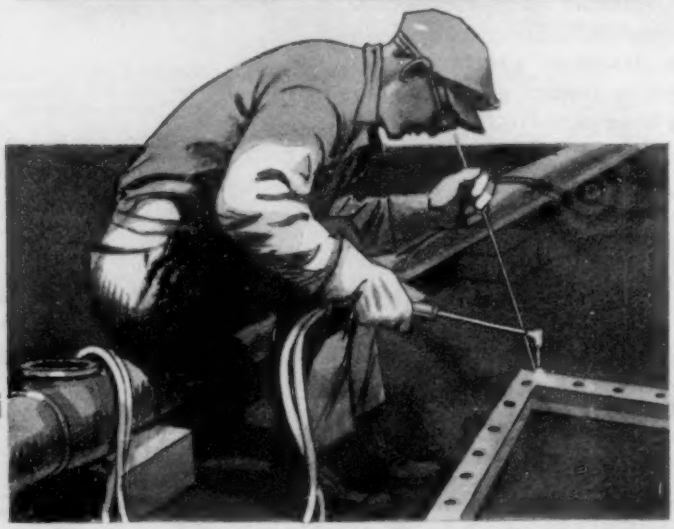
LONG ISLAND CITY, N. Y.
Thompson Ave. and Orton Street

SAN FRANCISCO
1050 Mission Street

STOCKS IN 39 CITIES

Oxweld

WELDING AND CUTTING APPARATUS



Large jobs and small— *by oxwelding*

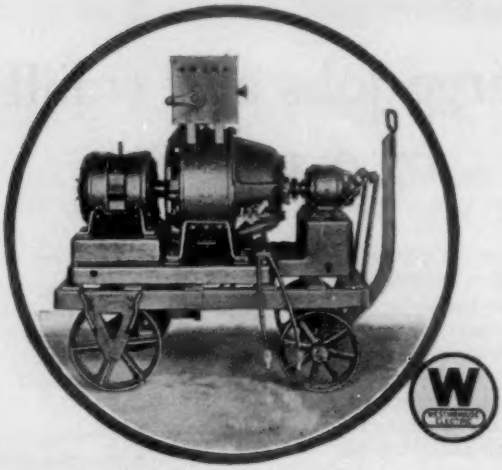
The modern cement kiln is an industrial mammoth 8 ft. in diameter and 125 ft. long and made of heavy ⅝" steel plates. It can be completely constructed by the oxy-acetylene welding process, and those so made are giving exceptionally good service. By the same method the tiny contact wires of a radio tube are joined together.

No other process of construction works so satisfactorily under different conditions. The kind, the analysis and the thickness of the metal to be welded may vary widely. The type of construction may be rugged or delicate, approximate or precise, yet the oxy-acetylene process is so flexible that it is easily adapted to every special need.

Prest-O-Lite dissolved acetylene is the original commercial welding gas. Because of it, much of the remarkable development of oxwelding and cutting has been possible.

Prest-O-Lite
DISSOLVED ACETYLENE

THE PREST-O-LITE COMPANY, INC.
Unit of Union Carbide and Carbon Corporation
General Offices: Carbide and Carbon Building
30 East 42d St., New York
31 Plants—101 Warehouses
22 years old and still growing



Welding—

An Insurance Against Breakdown Delays

READY for instant service in any corner of the shop—or outside—the Westinghouse Portable Arc Welder is really insurance against costly breakdowns and lost production. It has found wide application in practically every kind of plant where machinery repairs are required. It never balks—does its work quickly and effectively and is then ready for another job.

This sturdy machine has proved its usefulness in aiding production and in effecting big savings by the reclamation of parts. Its operation is extremely simple. There is just one rheostat —one point of control that assures the right potential for the arc you want. No brush shifting devices are necessary—the Westinghouse generator inherently stabilizes the arc.

The machine is so constructed mechanically that the entire equipment lies within the outline of the truck. There will be no side-swiping as it is moved about, and if pushed against the wall, no parts will be injured.

Westinghouse Electric & Manufacturing Company
East Pittsburgh Pennsylvania

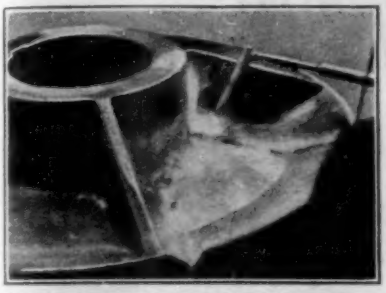
Sales Offices in all Principal Cities of the United States and Foreign Countries

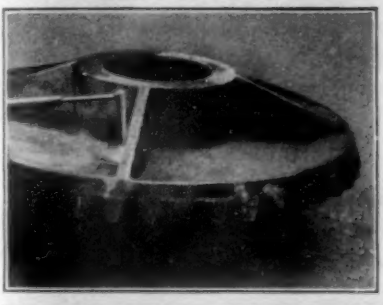
Westinghouse

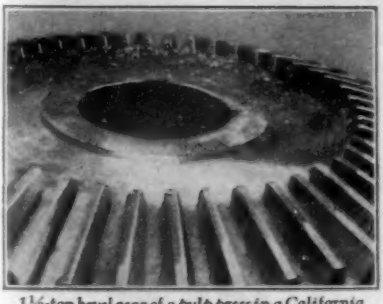
X91165

Portable Arc Welder

TOBIN BRONZE WELDING







1½-ton bevel gear of a pulp press in a California beet sugar factory Tobin Bronze welded.

Reclaimed this cracked gear at one-fifth the cost of a new casting

IT would have cost $500 to replace this 1½-ton casting. Tobin Bronze Welding repaired it for less than one-fifth of that cost. One welder and his helper "veed" the cracks on both sides in about five hours and did the welding job in five more.

Tobin Bronze has such a low welding temperature, 1650° F., that extensive pre-heating was not required. As a result the risk of distortion and metal shrinkage was avoided.

Cast iron properly welded with Tobin Bronze will not break at the weld because Tobin Bronze permeates the iron and knits the broken parts together in a permanent bond stronger than the original casting.

Many manufacturers who have proved the value of Tobin Bronze Welding for repair work are now using it to save time and money in manufacturing operations.

THE AMERICAN BRASS COMPANY
GENERAL OFFICES: WATERBURY, CONNECTICUT
Offices and Agencies in Principal Cities
Canadian Mill: ANACONDA AMERICAN BRASS LIMITED
New Toronto, Ontario

TOBIN BRONZE
REG. U.S. PAT. OFF.
WELDING RODS
EXCLUSIVELY AN ANACONDA PRODUCT

Before you settle on the type of machine— get the users viewpoint

Any Lincoln office below will put you in touch with a user near you whose experience covers many types of welders. Get his viewpoint based on experience.

They say

(a new list in each issue)

"Fulfilled all expectations in regards to speed, strength and ease of operation."

* * *

"We are welding the complete 5 ton truck body with your Lincoln welder. It sure gives good service."

* * *

"This machine has been in service from 1917 and is giving first-class service."

* * *

"I have used it on long jobs from 8 to 15 hours without any trouble whatever. It is the one machine that is always ready when the locomotives break down."

* * *

"We are using your Kathode welding rod. I think it is better than any other wire I have ever used."

"Stable Arc"

LINCOLN WELDER

Branch Offices
Baltimore
Boston
Buffalo
Charlotte, N. C.
Chicago
Cincinnati
Detroit
Des Moines
Grand Rapids

The Lincoln Electric Co.

General Offices and Factory:
Cleveland, Ohio

The Lincoln Electric Co. of Canada, Ltd., Toronto-Montreal
European Representatives: Allen-Liversidge, Ltd., London

Branch Offices
Indianapolis
Milwaukee
Minneapolis
New York City
Philadelphia
Pittsburgh
Rochester
St. Louis

Distributing agencies in all principal cities.

Exclusive Agencies with Stock:
Ft. Worth, Texas
New Orleans
Los Angeles
San Francisco

SWEDOX

WELDING RODS, WIRES and ELECTRODES

A Grade for Every Purpose

NONOX SWEDOX
LEKTROX SWEDOX
CASTOX
ARC CARBOX
GAS CARBOX
VANOX

STEELKOTE
LEKKOTE
CYLKOTE
MANKOTE
RAILKOTE

TENSKOTE
DUCTKOTE
DUCTILOX
NICKOX
RAILOX

KROMOX
MANGANOX
ALUMINOX
DRAWN ALUMINUM
BRAZOX

BRONZOX
BRONZKOTE
TOBIN BRONZE
MANGANESE BRONZE
MONEL METAL

TENSILOX
KROMKOTE
NICKOTE
VANKOTE
FLUXES

SEND FOR TESTING SAMPLE

We want every welder in the country—big or small—to be convinced of the *specialized superiorities* of SWEDOX products. We know that a trial *will* convince you. Hence the free offer. Try SWEDOX on your next welding job at our expense.

CHICAGO, ILL.
4545 S. Western Blvd.
Phone:
LaFayette 8500

Central Steel & Wire Company

DETROIT, MICH.
5001 Bellevue Ave.
Phone:
Lincoln 6780

"We Ship the Same Day"

WE ANNOUNCE

That on and after February 21st, 1927, our Offices, Factory and Service Department will be

MOVED

to LARGER QUARTERS without interrupting sales or service

AT

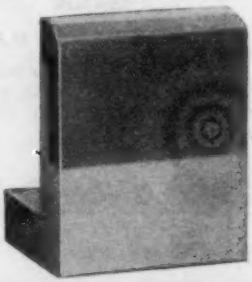
515 West 29th St., New York City

Phone number will be the same Chickering 0996-7-8

K-G WELDING & CUTTING CO., Inc.

BOUND VOLUMES JOURNAL NOW READY

A number of Bound Volumes of the Journal for 1926 have been bound in attractive book form. Members may obtain copies at $5.00, non-members $10.00.



ELKONITE
WELDING ELECTRODES

Elkonite is the ANSWER to long life electrodes in flash welding machines.

Wherever installed, in this type of work it has proved a revelation. We are prepared to place the facts at your disposal. Write Elkonite laboratory.

ELKON WORKS, INC.
Weehawken, N. J.

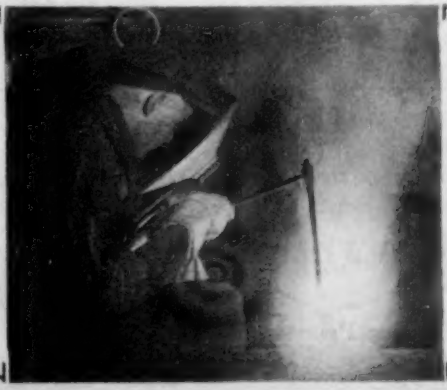
Sole licensees under General Electric Co. patents dated May 28, 1925, and Sept. 1, 1925. Other patents pending to Elkon Works, Inc.

Welding
ROEBLING
Wire

WELDING WIRE can always be relied upon for uniformity and perfect flowing quality. Roebling Electrodes are carried in all the standard sizes (14 inch lengths), also Gas Welding Wire (36 inch lengths). Other sizes required will be manufactured to order. Tell us the kind of metal you desire to weld—we will supply the wire which will give the best results.

Send for booklet A-529

John A. Roebling's Sons Company
TRENTON, NEW JERSEY



THERMIT WELDING

For heavy welding operations
in all fields

Railroad Industrial Marine

METAL & THERMIT CORPORATION
120 Broadway, New York
Pittsburgh Chicago Boston S. San Francisco Toronto

Why Experiment?

Torches
Regulators
Generators
Compressors
Manifolds
Preheaters
Paint Sprays
Carbide Lights
Catalog 54?

SINCE the infancy of the industry, expert engineers and skilled workmen have maintained the predominance of Milburn Equipment.
Its acceptance as standard equipment by large industrials, railroads and Government Departments the world over exemplifies Milburn leadership.

THE ALEXANDER MILBURN CO.
Baltimore, Md.

When you install UNA Rail Joints, you eliminate the gap between the rail ends without in any way changing the original steel structure of the running surface of the rail at the joint.

UNA WELDING AND BONDING COMPANY
CLEVELAND, OHIO

Welding Processes
Welding Rods

UNA

A.C.-D.C. Welders
Welding Supplies

PAGE-ARMCO
PROCESSED

Welding Wire *and* Electrodes

PROCESSED

To assure perfect results all Page Welding Wire and Electrodes are carefully treated and drawn especially for the type of work for which they are recommended. They are always uniform.

SHOP TESTED

In addition each type of Page Welding Wire is shop tested at frequent intervals under actual shop conditions to insure its high welding qualities.

PLAINLY MARKED

Each wire and rod is plainly stamped with the name and type of wire to eliminate guess work.

NATIONAL SERVICE

Complete stocks are maintained at all central points and users receive the promptest kind of delivery service.

Prove Page superiority right in your own shop. Write for samples and interesting literature.

PAGE STEEL & WIRE COMPANY

An Associate Company of the American Chain Co., Inc.

Bridgeport, Connecticut

District Offices: Chicago, New York, Pittsburgh, San Francisco

An Airco-Davis-Bournonville

Welding Torch

Style 7700

Combining all Essentials of Efficiency
Including Low Initial Cost
Economical Operating Cost and
Small Maintenance Cost

This Welding Torch combines the factors that established and maintained the high reputation of Davis-Bournonville Torches from the beginning of Oxyacetylene practice, with many new features of appreciable advantage and economy to the welder.

Manufactured in two sizes, with 4-in., 6-in., 9-in., and 16-in. extension tubes and welding tips from No. 1 to No. 12, graduated from 2½ cu. ft. to 128 cu. ft. acetylene capacity per hour.

AIR REDUCTION SALES CO.

Manufacturer of Airco Oxygen—Airco Acetylene, Calorene
Airco-National-Carbide
Airco-Davis-Bournonville Welding and Cutting
Apparatus and Supplies

18 District Sales Offices 54 Plants 96 Distributing Points

Home Office: 342 Madison Avenue, New York, N. Y.